THE DEVELOPMENT OF ATTENTION AND RESPONSE INHIBITION FOR 5- AND 7-YEAR-OLDS

By

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TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

II. DEFINING AND MEASURING ATTENTION 3

III. COMPONENTS OF ATTENTION 8

IV. DISENTANGLING ATTENTION AND REPOSE INHIBITION 13

Neuropsychology 14
Attention-Deficit Hyperactivity Disorder 18

V. METHOD

Participants 22
Stimuli 23
Procedure 25

VI. RESULTS 27

VII. DISCUSSION 35

Accuracy Data 35
Reaction Time Data 41
Implications for Previous Research 42
Alternative Explanations 43
Developmental Delay Model for ADHD 46
Strengths and Weaknesses 51
Summary 55

REFERENCES 58

Chapter Page

APPENDIXES 65

APPENDIX A - POWER ANALYSIS FOR ANOVA DESIGN 66

APPENDIX B - SCRIPT FOR CONDITIONS 68

APPENDIX C - FIGURES 71

APPENDIX D - IRB APPROVAL FORM..82

LIST OF FIGURES

Figures Page

1. Mean Number of Hit Responses for Each Age Group in Each Phase 72

2. Mean Number of Hit Responses in phases 1 and 2 for Each Age Group 73

3. Mean Number of Hit Responses in Phases 3 and 4 for Each Age Group 74

4. Mean Number of Silent Alarms in Phases 1 and 2 and Mean Number Of False Alarms in Phases 3 and 4 for Each Age Group 75

5. Mean Number of Silent Alarm Responses in Phase 1 and the Mean Number of False Alarm Responses in Phase 3 for Each Age Group 76

6. Mean Number of False Alarm Responses in Phases 1 and 3 for Each Age Group 77

7. Mean Number of Hit Responses in Phases 1 and 3 for Each Age Group 78

8. Mean Number of Hit Responses in Phase 2 and 4 for Each Age Group 79

9. Mean Reaction Time for Hits for Each Age Group and in Each Phase 80

10. Mean Reaction Time for False Alarms for Each Age Group And in Each Phase 81

CHAPTER I

INTRODUCTION

Research from the developmental and neuropsychological literature indicates that as children age, their ability to attend to information increases. This shift in attentional control is part of a larger collection of cognitive changes that occur between the ages of 5 and 7 years and is often referred to as the 5-7 shift (White, 1970). Piaget (1970) referred to this 5-7 shift as a change from pre-operational to concrete operational thinking. Examples of this shift are numerous. Research has shown that the greatest improvement in visual searching abilities occurs from 4- to 7-years of age (Enns & Cameron, 1987). A decrease in the disruptions of distracting stimuli has also been observed (Smith, Kemler, & Aronfreed, 1975) and 5-year-olds are more likely to have an improvement in performance if some kind of established set is in place (Day & Stone, 1980). Furthermore, children have shown ceiling effects on naming speed tasks by age 6 (Korkman, Linnankoski, & Lahti-Nuuttila, 1999) and tend to show significant improvement in memory tasks from ages 5 to 6 whereas only gradual improvement occurs to age 16 (Delis, Kramer, Kaplan, & Ober, 1994). Even some executive skills, such as simple planning, are achieved by age 6 (Welsh & Pennington, 1988).

The purpose of this paper is to differentiate between developmental improvements in attention and improvements in response inhibition for the 5-7 shift and to better define these constructs from a neuropsychological perspective. First, an attempt will be made to describe selective attention tasks and the components involved in the measurement of attention. Second, this review will attempt to disentangle the two constructs of attention and inhibition to demonstrate that these constructs may operate independently. Finally, other areas of study will be discussed, namely neuropsychological and attention-deficit hyperactivity disorder theory and research to provide insight into understanding the development of attention and inhibition.

CHAPTER II

DEFINING AND MEASURING ATTENTION

Studies using different paradigms in both auditory and visual modalities have shown that children's ability to selectively attend to appropriate stimuli present the most significant change between the ages of 5 to 7 (Enns & Akhtar, 1989; Enns & Cameron, 1987; Hedrick & Kunze, 1974; Maccoby & Konrad, 1966). Additionally, the younger children are much more susceptible to distraction and benefit the most from environmental assistance to remain focused (Day & Stone, 1980; Shepp & Barrett, 1991). Overall, the literature suggests that children between the ages of 5 and 7 show the most improvement on selective attention tasks, relative to older children and adults. Five-year-olds present difficulty in attending to relevant information and ignoring irrelevant information, while 7-year-olds present a very significant improvement in their ability to appropriately attend to all information.

One major difficulty in previous selective attention research is the lack of clarity for the construct(s) being measured. Selective attention tasks are assumed to measure attention. These tasks, however, are often confounded in that they measure multiple constructs simultaneously. For example, many selective attention tasks require a participant to attend and respond to target stimuli while ignoring non-target or irrelevant stimuli. These same tasks also require a behavioral "non-response" to non-target stimuli, thus measuring response inhibition. Response inhibition requires withholding or delaying a response, and represents a construct distinct from that of attention (Barkley, 1997; Roberts & Pennington, 1996; van der Molen, 2000). For clarity, a working definition will differentiate attention and response inhibition. These definitions are by no means all-inclusive, but represent a simple way of distinguishing two very complex concepts. For the current study, attention is defined as the ability to focus on the target stimulus and disregard irrelevant distracting stimuli, and requires a behavioral response (execution) to the target stimulus. Response inhibition, then, is defined as a non-response, or inhibition of responses, to non-target stimuli.

Tasks that measure selective attention vary on many levels. Some studies present clearer measures of attention than do others. One of the oldest studies of selective attention (Maccoby & Konrad, 1966) examined children ages 5, 7, and 9 years on a task presenting voices binaurally and dichotically. Children were instructed to listen to only one voice (male or female) and attention was measured by the number of correctly recalled words. This study found that the number of correctly recalled words increased with age, and the number of errors decreased. This paradigm is an example of an attentional task that has removed the need for immediately inhibiting responses and therefore presents a purer measure of attention. However, this paradigm required that the words be held in memory and recalled following voice presentation. Many would argue that working memory of this sort involves an additional set of processes, which may limit the conclusions about attention by these researchers (Barkley, 1997; Roberts & Pennington, 1996).

The visual modality has shown similar results with these age ranges. Smith, Kemler, and Aronfreed (1975) found that under numerous distraction conditions, children respond less to distraction with increasing age, and 5-year-olds are most disrupted under all distracting conditions. This paradigm required children to immediately respond "yes" if a visual stimulus had changed, or "no" if the stimulus had not changed. Again, this task is a purer measure of attention in that the child is required to make a behavioral response (yes or no), not inhibit a response as in response inhibition. In other words, behavioral responding is held constant across all trials. Therefore, the influence of this variable was not assessed.

Similarly, Cherry (1981) studied children ages 5 through 9 in which the child was asked to point to the picture that represented a word presented dichotically. The task consisted of three distracting conditions: white noise (nonlinguistic), speech backward (non-semantic words), and speech forward (semantic words). The left channel contained the signal and the right channel contained the competing stimulus all presented in a female voice. These researchers found that auditory selective attention skills improve with age. Again, this paradigm required the child to respond on every trial, thus holding inhibition constant.

This literature has shown that 5-year-olds perform poorly on selective attention tasks, being more susceptible to distraction and making fewer correct responses. In addition, this age group appears to benefit from cues or support that help focus attention. Day and Stone (1980) presented a perceptual set task in which children ages 5 and 8 were asked to identify whether a briefly presented target picture matched a standard picture. The child was instructed to give an answer on each trial by answering "yes" or "no." Day and Stone hypothesized that the presentation of the standard picture for a longer duration and before the target picture would create a momentary set to help the children avoid distraction. The results showed that 5-year-olds benefited from the momentary set and made more errors when distracters were present. In a very similar task, Shepp and Barrett (1991) presented 5- and 8-year-olds and adults with a selective attention task. The task was to present a relevant dimension (shape) and an irrelevant dimension (size) and the child was to respond to the target picture that matched that of the prime picture. Shepp and Barrett found that the greatest improvement in speed and accuracy was found between ages 5 and 8, rather than ages 8 to adult. Only the performance of the 5-year-old children improved when the irrelevant dimensions were perceptually congruent with the relevant stimuli. These studies provide additional support for the 5-7 shift and show that extraneous information (or stimuli) offers much more distraction for the youngest group. Furthermore, these paradigms also present a purer measure of attention because a response is required for each and every trial, thus removing the need for inhibitory processes. However, similar to the Smith et al. (1975) study, a response was required on every trial. Therefore, the development of response inhibition (a non-response) was not assessed.

Many studies measuring selective attention, however, do not hold response inhibition constant. These other studies have confounded attention with response inhibition. For example, Hedrick and Kunze (1974) examined children ages 4 to 9 by administering a dichotic auditory task in which distraction level and distraction content were altered. The content distractions were one of three conditions: meaningful and relevant words, meaningful but irrelevant words, and non-meaningful nonsense words. The level of distracters also had three conditions: the attended message was louder than the distracter, the attended message and the distracter were of equal volume, and the distracter was louder than the attended message. The results showed that the content distracter of meaningful and relevant words interfered more than the other two content distracters. The level of distracters showed that younger children made significantly more errors than older children when the volume of the irrelevant information was increased. Hedrick and Kunze concluded that the ability of children to respond to relevant stimuli in the presence of irrelevant stimuli improved with age. However, this improvement in responding to target information in the presence of distraction confounds attention and response inhibition because the child was instructed to respond to the target tone and inhibit responses to the non-target irrelevant tone.

Another study utilizing a visual selective attention paradigm instructed children ages 5 – 7 years to count silently the number of rare, target stimuli in the presence of frequent, non-target stimuli (Stauder, Molenarr, & van der Molen, 1993). The youngest children were allowed to say "ja" every time a target stimulus appeared. This study further separated children as conservers or nonconservers based on Piaget's conservation task. The results revealed significant differences between conservers and nonconservers on the number of correct responses and the number of errors when age was held as a covariate. That is, conservers performed more accurately on the visual selective attention task than did nonconservers. This presents some interesting findings to help explain the marked age improvements seen between 5- and 7-year-olds. However, this study is yet another example of one that confounds attention with response inhibition. Response inhibition was at least present for the youngest children who responded "ja" during each target stimuli, consequently requiring the withholding of the response.

CHAPTER III

COMPONENTS OF ATTENTION

While early research examined behavioral improvements, later researchers attempted to understand the mechanisms that underlie this developmental change. Lane and Pearson (1982) proposed three information processing stages that might account for this developmental shift: 1) encoding, 2) stimulus selection (attending to the relevant stimuli and ignoring the irrelevant), and 3) response selection. A similar model to that proposed by Lane and Pearson was published by Enns and Cameron (1987), who differentiated among three attentional components: search, which is similar to encoding; filtering, which refers to stimulus selection; and priming, or attention shifting. They examined 5-, 7-, and 24-year-olds in a visual paradigm that required the participant to respond to either a left- or a right-pointing target arrow. The conditions measuring the filtering (or selective attention) component presented the arrow in different areas of the screen (center vs. corner) flanked by a distracter arrow that participants were to ignore. Enns and Cameron reported significant improvements in response accuracy with age in all three components. However the ability to filter irrelevant information significantly improved from ages 5-7, but not from 7-24 years of age. These researchers concluded that the development of attention was not a single mechanism, but could be classified into at least two separate processes: searching (encoding) abilities and filtering (stimulus selection) abilities.

Ridderinkhof and van der Molen (1995) took a similar paradigm one step forward by measuring a number of physiological variables. In this study, children ages 5-6 years, 7-9 years, and 10-12 years of age were to respond to the direction of an arrow presented in the center of the computer screen. The target arrows were flanked by congruent arrows (pointing in the same direction), incongruent arrows (pointing in the opposite direction), or by pairs of diamonds (neutral). The researchers found that the incongruent arrows produced more interference, and response accuracy was significantly lower for the 5-6 year-olds, compared to the older groups.

Ridderinkhof and van der Molen (1995) also addressed the issue proposed by Lane and Pearson (1982). These researchers concluded that response selection, not stimulus selection, was responsible for the developmental change from 5 to 7 years of age. The basis of this argument stems from the idea that response selection is associated with the ability to resist distraction, and when irrelevant information was presented alongside target stimuli, the latency of behavioral responses was significantly delayed for the 5-6 year-olds as compared to the older groups. Stimulus selection then was measured by P3 latency. The P3 is a positive-going event-related potential (ERP) component that is elicited under an oddball selective attention paradigm. Although P3 is not exclusively a measure of selective attention, it is often used to measure the allocation of attentional resources (Donchin, Kramer, & Wickens, 1986; Ridderinkhof & van der Molen, 1995). The P3 latency showed developmental stability across all ages. Ridderinkhof and van der Molen reasoned that, if the latency of behavioral responses is significantly different for the age groups, but P3 latency is stable across ages, then response selection, not stimulus selection, is involved in the 5-7 shift. Furthermore, Ridderinkhof and van der Molen concluded that competing responses and the ability to inhibit inappropriate responses are major components involved in the developmental ability of a child to resist distraction.

These studies re-emphasize the important questions regarding the development of selective attention that were raised earlier. Enns and Cameron (1987) suggest that attention is classified into at least two different constructs and one of these constructs involves the ability to inhibit responses to irrelevant information that is similar to the target stimuli. Ridderinkhof and van der Molen (1995) attempt to explain those constructs involved in the ability to resist distractions as being response inhibition, which also involves inhibition of irrelevant information. These ideas suggest that selective attention tasks are measuring more than attention alone. Many selective attention tasks involve not only the ability to attend and respond to a target stimulus, but also involve the ability to inhibit responding to non-target stimuli. Therefore, selective attention tasks seem to measure both attention and response inhibition.

Contrary to Ridderinkhof and van der Molen's conclusion regarding attentional mechanisms, Bartgis, McGee, and Thomas (2002) found different results. Bartgis et al. attempted to investigate the 5-7 shift using a focused selective attention paradigm while measuring both behavioral and electrophysiological responses. Children heard stimuli in both ears, one ear being the relevant channel, and the other being the irrelevant. Targets were rare stimuli that only occurred 25% of the time and could occur in either ear. Standards were frequent stimuli that occurred 75% of the time and could also occur in either ear. Children were instructed to respond to targets in the relevant channel and to ignore targets in the irrelevant channel as well as all standards. Behavioral accuracy measures included hits (responses to targets in the relevant channel) and two types of errors or false alarms. The false alarms were target false alarms (TFAs: responses to targets in the irrelevant channel) and standard false alarms (SFAs: responses to standards in the relevant channel). The two electrophysiological measures were ERPs from P3 and Nd waveforms. The Nd wave measured the difference between standards in the attended ear and standards in the ignored ear, and theoretically assessed attention to the relevant channel. P3 was measured to the target stimuli in both the relevant and irrelevant channels, and therefore was assumed to assess attention to the target stimulus within the attended channel.

The results of the Bartgis et al. study showed that 7-year-olds were behaviorally more accurate in responding than 5-year-olds. Not only did 7-year-olds have more hits but they also had fewer false alarms than their younger counterparts. This finding is what would be expected from the developmental literature. The ERP results, however, were most interesting. Seven-year-olds showed significantly larger P3 amplitudes to the attended than to the ignored targets while 5-year-olds showed no differences. If P3 represents attention, this finding indicates that the 7-year-olds were processing the relevant stimuli to a greater extent than the irrelevant stimuli. Five-year-olds appeared to be processing both stimuli equally. Therefore Bartgis et al. concluded that both stimulus selection and response selection were responsible for the developmental shift seen from 5 to 7 years of age, as opposed to response selection alone as concluded by Ridderinkhof and van der Molen (1995).

The Ridderinkhof et al. (1995) and the Bartgis et al. (2002) studies both raise an interesting dilemma regarding selective attention literature. The ERP results of the Bartgis et al. study suggest that the shift in attentional abilities between 5 and 7 is more than just an increased ability to inhibit responses to irrelevant stimuli. The data from P3, which is independent of the behavioral response and represents stimulus processing, suggest than there is a difference in stimulus selection between these two age groups. This may indicate an attentional difference independent of response inhibition skills for the 5-7 shift. However, Ridderinkhof and van der Molen (1995) interpret their findings to mean that older children have better inhibitory control, which allows them to hold back during response competition and remove inhibition when the target response is needed.

Many paradigms that have examined attention with these young children have incorporated tasks that measure more than attentional processes alone. Many of these tasks also require the inhibition of competing responses as Ridderinkhof and van der Molen (1995) suggest. Furthermore, studies that represent purer measures of attention fail to recognize the importance of measuring response inhibition. This leaves researchers wondering about the true nature of developmental changes. These changes could be occurring in three ways: improved attention processes; improved response inhibition; or improvement in both processes that are part of a complex, coordinated set that functions and develops as a unit. Therefore, it is important to examine other bodies of literature that might be used to disentangle the two processes.

CHAPTER IV

DISENTANGLING ATTENTION AND RESPONSE INHBITION

After analyzing these empirical studies on the development of attention, one issue seems apparent. The issue regarding mechanisms involved in selective attention remains unclear. Many studies have utilized selective attention tasks and attributed developmental changes to improvement in attention. However, many of these paradigms may have confounded differing constructs. Few researchers have attempted to discriminate between those components of these tasks that describe attention versus those components that depict response inhibition. At this point we need to expand the concept of response inhibition beyond the narrow sense in which we have been using it. Response inhibition is typically included among a cluster of processes that are collectively referred to as executive functions. Included in this cluster are working memory, self-regulation, goal-directed planful behavior, organization, and other higher order cognitive processes (Barkley, 1997; Roberts & Pennington, 1996; van der Molen, 2000).

Only one study has been found to assess executive skills of normal developing children ages 5 to 7 (Welsh, Pennington, & Groisser, 1991), however a few studies utilize younger or older age groups (Dowsett & Livesey, 2000; Travis, 1998). Welsh and colleagues (1991) measured children ages 3 to12 years of age on a battery of tasks said to measure executive functioning. One of the major goals of this research was to identify the ages at which adult-level competence was reached for each task. One such task required children to search for a visual target stimulus in the presence of distracter items. The measure was an efficiency score, which was derived from taking the response time divided by hits minus false alarms (or errors). The results of this study showed that children were indistinguishable from adults on the visual search task by age 6 and the major developmental shifts occurred from 3 to 4 years of age, and from 5 to 6 years. Although this task is very similar in nature to the selective attention tasks reviewed in the attentional literature, the conclusions described improvement in executive functioning rather than in attention (Welsh et al., 1991). This is further evidence to support the idea that these two constructs are not only confounded in the attentional literature, but also literature regarding executive functioning.

This expansion from response inhibition is made because the literature that is about to be reviewed deals with the larger category of executive functions. (However, the focus of the proposed research will remain the more circumscribed concept of response inhibition.) The focus will now be on neuropsychological studies and research into attention deficit disorders to attempt to disentangle attention and executive functions.

Neuropsychology

Neuroanatomical dissociation can provide insight into understanding the development of attention and executive functioning. To understand the neuroanatomical structures involved in attention, researchers have turned to investigating brain dysfunction and neuroimaging. Posner and colleagues (Posner & Dehaene, 1994; Posner & Peterson, 1990) proposed two distinct systems involved in selective attention. The posterior system, responsible for stimulus selection and attention shifting, and the

SURVIVAL, CAUSE-SPECIFIC MORTALITY, AND TELEMETRY EFFECTS ON NORTHERN BOBWHITES

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TABLE OF CONTENTS

CHAPTER PAGE

INTRODUCTION....1

STUDY AREA....4

METHODS....5

DATA ANALYSIS....7

Survival....7
Cause-Specific Mortality....8
Radio-Collared vs. Nonradio-Collared....8
Censor Period....9

RESULTS....9

Survival....9
Cause-Specific Mortality....12
Radio-Collared vs. Nonradio-Collared....12
Censor Period....12

DISCUSSION....17

Survival....17
Cause-Specific Mortality....19
Radio-Collared vs. Nonradio-Collared....20
Censor Period....22

LITERATURE CITED....24
APPENDIX 1....29
APPENDIX 2....31

LIST OF TABLES

Table Page

Table 1. Variation in reported annual survival (%) and cause-specific mortality (%) of northern bobwhites as determined with radio-telemetry methodology..3

Table 2. Seasonal and annual survival rates (95% CL) of northern bobwhites estimated from radio telemetry data collected from 1 September 2000 to 31 May 2002 using different censor periods, Mesa Vista Ranch, Roberts County, Texas..10

Table 3. Bootstrap means for days of survival and 95% CL from capture to death for sex-age classes of northern bobwhites on Mesa Vista Ranch, Roberts County, Texas, during 9 September–7 January 2000–2001, 13 September–7 January 2001–2002, and pooled (9 Sep 2000– 7 Jan 2002)..13

Table 4. Cause-specific mortality rates (95% CLs) of northern bobwhites calculated from radio telemetry data collected between 6 September 2000 and 31 May 2002, Mesa Vista Ranch, Roberts County, Texas...14

Table 5. *G*-test for independence of cause of mortality from time since capture for northern bobwhites radio collared between 6 September 2000 and 7 January 2002, Mesa Vista Ranch, Roberts County, Texas...15

Table 6. Comparison of survival estimates of northern bobwhites and 95% CL from line transect method and radio telemetry, Mesa Vista Ranch, Roberts County, Texas, 2000–2002...16

LIST OF FIGURES

Figure Page

Fig. 1. Survival curves (A, C) and derivatives (B, D) for northern bobwhites radioed for the periods 6 September 2000–7 January 2001 and 13 September 2001–7 January 2002, Mesa Vista Ranch, Roberts County, Texas...18

INTRODUCTION

Knowledge of survival rates and mortality sources is useful in understanding the population dynamics of northern bobwhites. Historically, the annual survival rate of bobwhites was thought to be about 20% based on interpretation of age ratios determined from harvest data (Guthery 1997). The 20% figure best fits mid-latitude populations, with survival rates being <20% in northern-latitude populations and >20% in southern-latitude populations (Guthery 2002:47).

Previous work on cause-specific mortality for bobwhites indicates that sources of mortality vary among populations (Table 1). Susceptibility to predators changes with season (Robel 1965, Burger et al. 1995, Taylor et al. 2000), age class (Robel 1965), and sex (Burger et al. 1995). In Mississippi, survival differed between sexes with females having a higher survival rate than males during the breeding season (Taylor et al. 2000). In Missouri, males had a greater avian mortality rate (0.27 spring–fall) than females (0.20 spring–fall; Burger et al. 1995). Higher male mortality from avian predators in the spring was attributed to increased exposure through calling from whistling posts (Burger et al. 1995). The general trend places heaviest avian mortality in the fall and winter seasons and heaviest mammalian mortality in the spring and summer (Curtis et al. 1988, Burger et al. 1995, DeMaso et al. 1998).

Radio telemetry has become a common tool in wildlife research (White and Garrot 1990:xi). In the last 20 years radio transmitters have become smaller and more technologically advanced. This allows researchers to attach transmitters to smaller animals and receive information that is more reliable. Telemetry data have commonly been used for estimating survival (Robel 1965, Liu et al. 2000) and cause-specific mortality (Burger et al. 1995, Taylor et al. 2000).

The main assumption of telemetry studies is that the radio-collared sample reflects an unbiased picture of the dynamics of the population without influence from the radio transmitter (White and Garrot 1990:27), and that a radio-collared individual behaves, survives, and experiences conditions identical to a nonradio-collared individual.

Survival rates reported in some previous telemetry studies were too low to permit population persistence, thus drawing into question the assumption that radioed bobwhites present an unbiased representation of population dynamics. According to Guthery (1997), a population of bobwhites would need to produce 18 juveniles/surviving adult to persist at an annual survival rate of 0.053 as reported by Burger et al. (1995). Production of 18 juveniles/adult is impossible for a population to reach, given normal survival of adults (Guthery et al. 2000).

The possible bias in telemetry estimates of bobwhite survival raises 2 issues in the conduct of telemetry research. First, survival rates estimated from telemetry should be checked against survival rates estimated independent of telemetry data. The second issue is the application of the correct censor period for radioed bobwhites. When a radio collar is attached to a bobwhite there is a period of time required to recover from capture and handling and adjust to the radio (Urban and Klimstra 1972). This period of adjustment is known as the censor period. Gilmer et al. (1974) inferred that there was a lower survival rate for radio-collared birds during the period of adjustment to radio transmitter attachment due to increased susceptibility to predation. At the end of the censor period, researchers assumed that the radio does not adversely affect the behavior of the radioed individual. A 7-day censor period has become the most commonly used period (Curtis et

Table 1. Variation in reported annual survival (%) and cause-specific mortality (%) of northern bobwhites as determined with radiotelemetry methodology.

				Cause-specific mortality			
Source	County and state	Years	Annual survival	Mammal-ian	Avian	Harvest	Other
Curtis et al. 1988	Leon , FL; Hoke and Cumberland , NC	1985–1988	6.1	35.6	64.4	0.0	0.0
Mueller et al. 1988[a]	Leon, FL	1986		29.0	71.0	0.0	0.0
Burger et al. 1995	Macon and Knox, MO	1989–1992	5.3	27.4	30.5	29.3	12.7
Liu et al. 2000[b]	Trinity, TX	1990–1992		9.1	57.6	0.0	33.3
Taylor et al. 2000[b]	Oktibbeha, MS	1993–1996		41.7	21.4	0.0	36.9

[a]Time span for study was 45 days.

[b]Time span for studies was breeding season only.

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al.1988, Pollock et al. 1989, Robinette and Doerr 1993, Suchy and Munchel 1993, Burger et al. 1995, Townsend et al. 1999) but this period is based on tradition, not on critical analysis. Other censor periods reported include 0 days (Mueller et al. 1993), 10 days (Puckett et al. 1995), and 14 days (Mueller et al. 1988, DeVos and Mueller 1993).

My primary objective was to obtain descriptive data on seasonal and annual survival and cause-specific mortality rates of bobwhites in the Texas Panhandle. Secondary objectives were to (1) compare survival rates of radioed bobwhites with survival estimates from line transect density estimates and (2) estimate the optimal censor period under conditions prevailing during the study. The secondary objectives were established because of possible bias in survival rates estimated with radio-collared bobwhites.

STUDY AREA

The study was conducted on the Mesa Vista Ranch (11,332 ha) in the Texas Panhandle during September 2000–May 2002. The area is in the Rolling Plains vegetation region (Hatch and Pluhar 1993:2). The study area was 32 km north of Pampa, Texas, along the Canadian River in Roberts County. Research was concentrated on Tallahone Pasture (802 ha). This pasture was chosen because it contained a representative sample of habitat types found throughout the ranch.

Roberts County is in a cool temperate climate zone (Wyrik 1979:71). Generally mild winters are characterized by frequent abrupt temperature changes (Wyrik 1979:2). Roberts County receives on average 53 cm of precipitation (Wyrik 1979:2).

There are 7 soil types on the study site ranging from fine sand to clay. Likes loamy sand was found on upland areas with 1–8 % slope (Wyrik 1979:20).

Likes–Tascosa association can be found on hills. Lincoln fine sand was found in frequently flooded areas. Obaro Quinlan was a loam occurring on rolling ridges and hills. Spur clay loam occurs on occasionally flooded areas. Sweetwater silty clay loam occurs in wet bottomland. Tivoli fine sand was found on upland areas.

I defined 9 habitat types inside the study pasture. These included riparian, grass bottomland, grass bottomland with salt cedar (*Tamarix ramosissima*), upland grass, sand sagebrush (*Artemisia filifolia*), mixed shrub, other wooded area, hilltop, and other cover types. Cottonwood trees (*Populus deltoides*) along dry creek beds characterized riparian habitat. Grass bottomland habitats were characterized by water-tolerant species in lowland areas where the water table was near the surface. Grass bottomland with salt cedar was the same as grass bottomland with the addition of salt cedar. Western wheatgrass (*Elytrigia smithii*) and other upland grasses characterized upland grass habitat. The presence of sand sagebrush characterized sand sagebrush habitat. Mixed shrub habitat contained a mixture of sand sagebrush, sand plum (*Prunus augustifolia)*, and skunkbush (*Rhus aromatica*). Other wooded areas were any areas with tree coverage other than riparian habitat, composed primarily of hackberry (*Celtis laevigata*). Hilltop habitat was located on sparsely vegetated hilltops. The vegetation there was made up of various short grasses, forbs, and mosses. The class, other cover types, contained any habitat not included in the other habitat types. These included water holes, construction areas, roads, and structures.

METHODS

Bobwhites were trapped using funnel traps baited with a mixture of corn, wheat, and milo (Stoddard 1931:442). Trap sites were prebaited a week prior to a trap being set.

Traps were checked twice daily, at midday and at dusk. When bobwhites were caught they were sexed, weighed, aged, and fitted with leg bands. A portion of the bobwhites captured were fitted with 5–6-g, bib-style radio transmitters (American Wildlife Enterprises, Monticello, Florida, USA) to monitor survival, cause-specific mortality, and censor period. During the first year, trapping concentrated on females with the goal of obtaining a ratio of 80% female to 20% male radio-collared bobwhites in an attempt to have a large sample of females leading into the breeding season. The second year, any bobwhite of adequate size (>170 g) was radio-collared to obtain a larger sample of radio-collared bobwhites.

I monitored survival using radio telemetry. Bobwhites were monitored by triangulation at least twice a week throughout the year. When mortality was detected the radio transmitter was located and cause of mortality estimated. Cause of mortality was determined from evidence obtained at and around the site where the radio transmitter was found (Curtis et al. 1988), including bobwhite remains, location, tracks, and marks on the transmitter and antenna.

Bobwhite density estimates were obtained using the line transect method (Ratti et al. 1983, Guthery 1988, Buckland et al. 1993). Eight transects running north–south were laid out across the pasture to provide representative coverage of the entire pasture. Transects ranged in length from 0.84 km to 2.9 km, for a total length of 16 km. Start and end points were fixed using a GPS II plus (Garmin, Olathe, Kansas, USA.) hand-held unit. Transects were walked in mid-March and mid-October of each year. Transect counts were conducted by having an observer walk a transect recording the coveys encountered, distance from the transect line to the point of flush at a right angle to the transect line, and habitat type where the covey flushed. Each of the 8 transects were walked by each observer during a 2–5-day period. Transects were conducted during 2 counting periods each day; in the morning starting shortly after sunrise continuing until 2 transects had been walked by the observer, and about 3 hours before sunset and again continuing until 2 transects were walked by the observer. Data were then used to calculate an effective strip width and density in birds per hectare (Ratti et al. 1983, Buckland et al. 1993:105).

DATA ANALYSIS

Survival

Survival was calculated using the Kaplan-Meier staggered entry method (Pollock et al. 1989). Data used for calculation were pooled over sex and age classes. If contact was lost with a bobwhite and it was not located in 2 weeks, it was right censored and not counted as a death. If the bobwhite was later found it was added back to the sample in the proper category. Multiple survival rates were calculated using different censor periods (0, 7, 14, and 21 days). Survival was estimated seasonally for the fall–spring (Sep–May), spring (Apr–May), and fall (Oct–Mar). Comparisons were made among seasons and years by assessing overlap in confidence intervals. Additionally, annual (Sep–Aug) and breeding season (Apr–Sep) survival rates were calculated for 2000–2001.

Justification for pooling sex-age classes for estimation of survival rates was assessed with bootstrap simulation (Mooney and Duval 1993, Davidson and Hinkley 1997) of elapsed time (days) from capture to death for individuals in each class. I considered elapsed time from capture to death an index of survival rate, and I used bootstrapping because of small samples. One thousand samples of size n_i, where n_i is the number of sample individuals in sex-age class i, were drawn to compute bootstrap means for a sex-age class based on 2000–2001 and 2001–2002 data. Differences in survival were determined using 95% CLs based on the distribution of bootstrap means.

Cause-Specific Mortality

Cause-specific mortality was calculated using the MICROMORT computer program (Heisey and Fuller 1985). To increase numbers for calculation purposes, causes of mortality were classified into 4 classes. The classes were mammal, avian, hunter, and other (all mortality not included in the previous classes). Cause-specific mortality was calculated seasonally for the fall–spring (Sep–May), spring (Apr–May), and fall (Oct–Mar). Comparisons were made among seasons and years by assessing overlap in the 95% CLs.

G-tests were conducted to determine if sources of mortality were independent of time since capture. The test was done with 3 cutpoints because the results of the test may depend on arbitrary classifications. The cutpoints (days) used were (A) $\leq$20, 21–40, and >40; (B) $\leq$14, 15–21, and >21; (C) $\leq$7, 8–21, and >21.

Radio-Collared vs. Nonradio-Collared

Survival rates for nonradio-collared bobwhites were calculated from density estimates obtained from line transect method (Ratti et al. 1983, Guthery 1988, Buckland et al. 1993). Survival was calculated using the formula $S = D_S/D_F$ where D_S is the spring density estimate and D_F is the fall density estimate (Ratti et al. 1983). Variance was calculated following procedures in Ratti et al. (1983). These rates were compared to survival estimates from telemetry data for the period between fall and spring line-transect counts. Ninety-five percent CLs were used to evaluate differences in survival between radio-collared and nonradio-collared populations.

Censor Period

To estimate the correct censor period I developed survival curves for bobwhites radio tagged between 1 September and 7 January 2000–2001 ($n = 62$) and the same time period 2001–2002 ($n = 46$). Regardless of capture date, bobwhites were moved to a common starting point (day 0). Then the number of bobwhites surviving was plotted as a function of elapsed time for 100 days. Survival curves were smoothed using a 3-point moving average (Kendall and Ord 1990:28). The derivative of the smoothed survival curve was determined numerically (Anonymous 2002). The optimal censor period occurred when the instantaneous rate of increase stabilized.

RESULTS

Survival

Survival estimates for the first year (2000–2001) were based on 99 radio-collared bobwhites (15 ad F, 44 juv F, 8 ad M, and 32 juv M). The second season (2001–2002) estimates were based on 90 radio-collared bobwhites (24 ad F, 22 juv F, 16 ad M, and 28 juv M).

Estimated survival rates differed over censor period, season, and year (Table 2). The highest estimate for survival in 2000–2001 was from a censor period of 14 days. Fall–spring (Sep–May) survival of 2000–2001 (0.07) was lower than 2001–2002 (0.30). Survival in 2000–2001 was much lower (0.13) than 2001-2002 (0.44). Spring survival was higher as well in 2001–2002 (0.83) than in 2000–2001 (0.62). Additionally, a yearly (1 Sep–31 Aug) and spring–summer (1 Apr–31 Sep) were calculated for 2000-2001.

Confidence limits for days survived from capture to death overlapped

Table 2. Seasonal and annual survival rates (95% CL) of northern bobwhites estimated from radio telemetry data collected from 1 September 2000 to 31 May 2002 using different censor periods, Mesa Vista Ranch, Roberts County, Texas.

Period[a] Censor period (days)	2000–2001	2001–2002
1 Oct–31 Mar		
0	0.01 (0.00–0.02)	0.44 (0.35–0.52)
7	0.13 (0.08–0.18)	0.44 (0.36–0.54)
14	0.20 (0.13–0.27)	0.36 (0.28–0.43)
21	0.12 (0.07–0.17)	0.34 (0.25–0.42)
1 Apr–31 May		
0	0.52 (0.32–0.72)	0.81 (0.71–0.92)
7	0.62 (0.46–0.78)	0.81 (0.71–0.92)
14	0.61 (0.45–0.77)	0.81 (0.70–0.91)
21	0.60 (0.44–0.76)	0.77 (0.65–0.89)
1 Sep–31 May		
0	0.06 (0.03–0.09)	0.30 (0.22–0.37)
7	0.07 (0.04–0.10)	0.30 (0.23–0.38)
14	0.08 (0.05–0.11)	0.23 (0.17–0.29)
21	0.02 (0.01–0.03)	0.26 (0.18–0.33)
1 Apr–31 Sep		
0	0.13 (0.00–0.30)	
7	0.32 (0.13–0.51)	

14	0.38 (0.21–0.55)
21	0.31 (0.18–0.44)
1 Sep–31 Aug	
0	0.03 (0.01–0.05)
7	0.04 (0.02–0.06)
14	0.05 (0.02–0.07)
21	0.00 (0.00–0.00)

[a] 1 Oct–31 Mar = fall, 1 Apr–31 May = spring, 1 Sep–31 May = fall–spring, 1 Apr–31 Sep = spring–summer, 1 Sep–31 Aug = annual.

considerably between sex and age classes (Table 3). The exception was in 2001–2002. Bootstrapping indicated that days survived differed ($P \sim 0.01$): adult females had greater survival (220.0) than juvenile males (117.8).

Cause-Specific Mortality

Mortality rates did not differ between season or year (Table 4). The mortality rate from other sources for the annual rate in 2000–2001 was higher than expected. Hunter related mortality contributed only a small portion to the total mortality of bobwhites in each year.

The *G*-test results showed that in the majority (75%) of tests sources of mortality were independent of time since capture (Table 5). Tests that showed significance were with a 7-day cutpoint. When tests indicated a lack of independence, frequencies of mammal deaths were roughly double avian deaths in the first 3 weeks and then became roughly equal after 3 weeks (Appendix 2).

Radio-Collared vs. Nonradio-Collared

Telemetry and transect data were analyzed to check for a difference in estimated survival rates between radio-collared and nonradio-collared bobwhites. Confidence intervals from line transect survival estimates overlapped those obtained from telemetry (Table 6). Point estimates of survival for both methods were similar as well.

Censor Period

Survival curves showed different properties between years (Fig. 1). The probability of survival for 100 days in 2000–2001 was 0.42 ± 0.097 SE compared with 0.63 ± 0.103 SE in 2001–2002. The absolute rate of increase decreased (meaning survival increased) for a period of about 45 days in 2000–2001; this is the first

Table 3. Bootstrapping means for days of survival and 95% CL from capture to death for sex-age classes of northern bobwhites on Mesa Vista Ranch, Roberts County, Texas, during 9 September–7 January 2000–2001, 13 September–7 January 2001–2002, and pooled (9 Sep 2000–7 Jan 2002).

Year	Sex	Age	$\bar{x}$	SE	LCL	UCL
2000–2001	F	Ad	73.90	25.54	13.49	134.26
	F	Juv	79.30	12.56	53.45	105.17
	M	Ad	85.70	66.39	0.00	371.34
	M	Juv	121.00	24.55	68.67	173.33
2001–2002	F	Ad	220.00	17.56	174.86	265.14
	F	Juv	159.50	25.64	104.47	214.46
	M	Ad	187.70	26.02	129.76	245.69
	M	Juv	117.80	24.48	64.89	170.68
Pooled	F		115.70	12.02	91.60	139.80
	M		134.30	14.54	104.90	163.60

Table 4. Cause-specific mortality rates (95% CLs) of northern bobwhites calculated from radio telemetry data collected between 6 September 2000 and 31 May 2002, Mesa Vista Ranch, Roberts County, Texas.

Period[a] Source	2000–2001	2001–2002
1 Oct–31 Mar		
Avian	0.42 (0.26–0.58)	0.19 (0.07–0.31)
Mammal	0.30 (0.15–0.45)	0.22 (0.10–0.35)
Hunter	0.06 (0.00–0.13)	0.02 (0.00–0.05)
Other	0.06 (0.00–0.18)	0.09 (0.00–0.20)
1 Apr–31 May		
Avian	0.13 (0.01–0.25)	0.02 (0.00–0.05)
Mammal	0.22 (0.08–0.36)	0.07 (0.00–0.14)
Other	0.03 (0.00–0.08)	0.09 (0.02–0.17)
1 Sep–31 May		
Avian	0.30 (0.04–0.56)	0.32 (0.14–0.52)
Mammal	0.22 (0.02–0.42)	0.22 (0.10–0.34)
Hunter	0.04 (0.00–0.10)	0.02 (0.00–0.04)
Other	0.37 (0.00–0.87)	0.12 (0.02–0.21)

[a] 1 Oct–31 Mar = fall, 1 Apr–31 May = spring, 1 Sep–31 May = fall–spring.

Table 5. *G*-test for independence of cause of mortality from time since capture for northern bobwhites radio collared between 6 September 2000 and 7 January 2002, Mesa Vista Ranch, Roberts County, Texas.

Time period Time class	*G*	*P*
6 Sep 2000–7 Jan 2001		
A[a]	7.28	>0.100
B[b]	6.34	>0.100
C[c]	9.36	>0.050
6 Sep 2000–7 Jun 2001		
A	4.60	>0.250
B	8.74	>0.050
C	13.56	>0.005
13 Sep 2001–7 Jan 2002		
A	5.36	>0.250
B	3.20	>0.500
C	9.48	>0.025
6 Sep 2000–7 Jan 2002		
A	6.38	>0.100
B	10.30	>0.025
C	14.86	>0.005

[a]A cutpoints of ≤20 days, 21–40 days, and >40 days.

[b]B cutpoints of ≤14 days, 15–21 days, and >21 days.

[c]C cutpoints of ≤7 days, 8–21 days, and >21 days.

Table 6. Comparison of survival estimates of northern bobwhites and 95% CLs from line transect method and radio telemetry, Mesa Vista Ranch, Roberts County, Texas, 2000–2002.

	Line transect			Telemetry		
Period	Survival	LCL	UCL	Survival	LCL	UCL
18 Oct 2000–18 Mar 2001	0.11	0.02	0.20	0.23	0.15	0.30
15 Oct 2001–15 Mar 2002	0.64	0.22	1.00	0.55	0.45	0.65

approximation of censor period for this sample. Adjustment from capture and handling manifested as a trend rather than a threshold, based on the derivative of the survival curve. If adjustment is a trend then each individual bobwhite in the population may require a different amount of time to adjust to the attachment of radio transmitters. This period of adjustment took place over a span of about 25 days (from day 20 to day 45, Fig. 1B). In 2001–2002, the optimal censor period was 0 days.

DISCUSSION

Survival

Pooling of the sex and age classes within years for survival calculation does not produce bias in the estimate of population performance if classes survive at the same rate such as they did in 2000–2001 (Table 3). If classes did not survive at the same rate, such as in 2001–2002, the pooling can still be justified. Such pooling can present an unbiased picture of population behavior if the classes in the sample are represented in proportion to their occurrence in the population. This was approximated by attaching radio collars to every bobwhite of adequate size regardless of sex and age. In the absence of some sort of trapping response the corresponding proportions of each sex and age class should have radio collars as in the population.

The winter of 2000–2001 (3 weeks of snow cover) was more severe than the winter of 2001–2002 (0 weeks of snow cover) based on weather records maintained on the study area. The total energy expenditure per individual bobwhite during the third week in September through the second week in March was estimated at 7,802 kcal in 2000–2001 versus 7,440 kcals in 2001–2002 (Case and Robel 1974). The difference in winter severity might explain the difference in survival rate between years (Table 2).

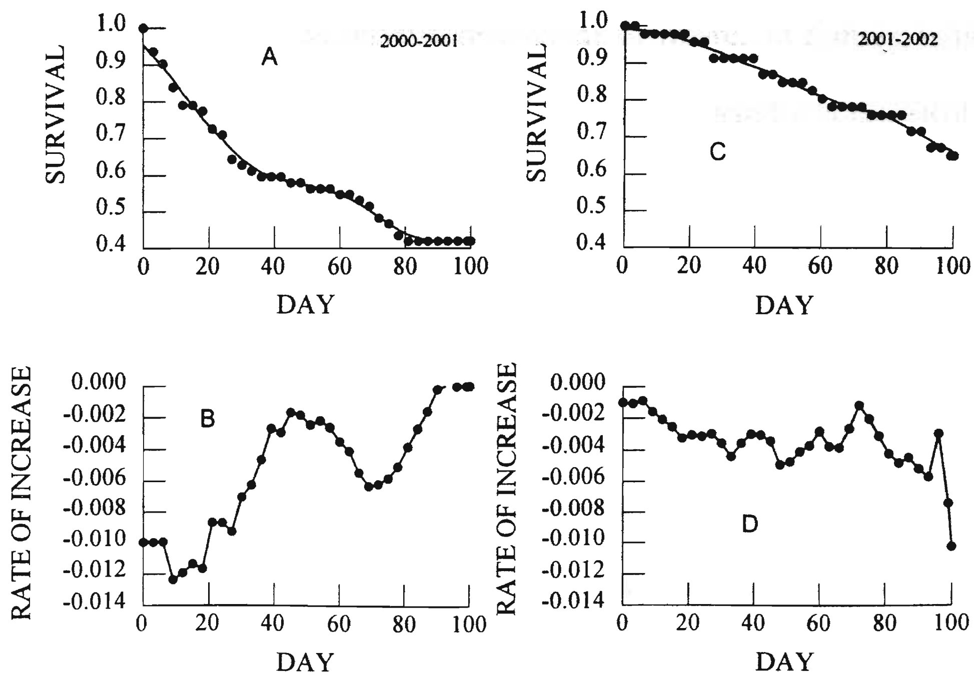

Fig. 1. Survival curves (A, C) and derivatives (B, D) for northern bobwhites radioed for the periods 6 September 2000–7 January 2001 and 13 September 2001–7 January 2002, Mesa Vista Ranch, Roberts County, Texas.

Survival rate did not vary over year and season in this study, and was not consistent with other reported survival rates in the literature. In Kansas, winter survival was found to be lower for juveniles (0.27 of ad survival) than for adults (Robel 1965). Survival of bobwhites with broods (0.78) during the first 21 days post hatch was less than those without broods (0.90; Burger et al. 1995). This was attributed to the high cost of parental care (Burger et al. 1995).

Comparison of long-term survival estimates for stable populations at equal latitudes can further illuminate direction of population trends. Long-term annual survival estimates for hunted populations should decrease with increasing latitude (Guthery 2000:116). Long-term survival for north Texas should be close to 20% per year (Guthery 2000:116). The 2-year data for the Mesa Vista Ranch suggested an average annual survival rate of 11.8%. This average is based on 4% survival in 2000–2001 (Table 2, 7-day censor period). The annual survival rate for 2001–2002 was estimated at 19.6%. This estimate was obtained by using data for the period 1 September–31 May (Table 2, 7-day censor period). I assumed constant daily survival for the period, estimated the daily survival rate (0.9956), and raised this rate to the power 365 to obtain an estimate of the annual survival rate.

Cause-Specific Mortality

The results of this study varied somewhat with findings reported in the literature. Mortality from different causes has been reported to vary over season (Robel 1965, Curtis et al. 1988, Burger et al. 1995, DeMaso et al. 1998). Previous studies have described a pattern of cause-specific mortality with avian mortality being highest in the fall and winter and mammalian mortality being highest in the spring and summer (Curtis et al.

1988, Burger et al. 1995, DeMaso et al. 1998). This study did not show any difference in mortality rates between season or year with the exception of hunting losses, which only occurred in the fall.

Cause-specific mortality rates reported for radio-collared bobwhites could be biased due to visibility of the radio transmitter (Mueller et al. 1988, Burger et al. 1991). The transmitter was preened under feathers and made of similar colors to bobwhite plumage with the antenna running on top of the back. The antennae or odd feather patterns produced from the transmitter could possibly be visible to predators. This would be most relevant to avian predators, which hunt from above by sight.

Calculated cause-specific mortality rates are dependent on observations in the field. For mortality rates to be accurate, cause of death must be correctly identified. Most deaths were not known with certainty, except for those deaths directly observed. Possible future research should ascertain the accuracy of these observations.

Several anomalies presented themselves from the data. First, the high rate of mortality from other causes during the first year was a result of high mortality from this category at the beginning of the study when the radio-collared population numbers were lower. Second, mortality from hunting occurred only in the fall (Nov–Feb) due to hunting season in Texas.

Radio-Collared vs. Nonradio-Collared

Researchers who have compared survival rates of telemetered versus wild birds have reported contradicting results. This contradiction lacks intensive research for bobwhites (Corteville et al. 2000). Mueller et al. (1988) found that short-term mortality was virtually the same between radio-marked and nonradio-marked bobwhites. By flushing the covey containing the radio-collared bobwhite and counting the number of bobwhites flushed, a count of nonradio-collared bobwhites was obtained (Mueller et al. 1988). Mortality rates between radio-collared bobwhites (0.27) and nonradio-radio collared bobwhites (0.24) were similar for the first 45 days post capture. Osborne et al. (1997) studied pen-reared bobwhites with 2 different types of harnesses, and found that survival was less for bobwhites with bib-style harnesses than those without or with backpack harnesses. They expressed that this fact could bias results of survival and nesting studies, and recommended less stressful alternatives (whistle counts) when possible. At the Packsaddle Wildlife Management Area in western Oklahoma, Parry et al. (1997) found that radio-marked bobwhites (0.30 chance of harvest) were less likely to be harvested than were bobwhites with only a leg band (0.39 chance of harvest). They suggested that radio-tagged bobwhites became accustomed to people being close and did not flush as quickly as bobwhites with leg bands only.

The lack of difference between survival estimates from radio telemetry and line transect method (Table 6) could indicate that estimates reflected the population dynamics on the study site. Alternatively, the lack of difference could be a factor of the method of sampling. Line transect and radio telemetry survival estimates produce a large variance. For differences to be detected the estimates would need to be at extremes (survival equal 1.00 or 0.001).

A source of bias in telemetry estimates could arise from capture and handling. Time spent in traps by bobwhites could increase injuries, harassment by predators, and possibly death (Mueller et al. 1988). Procedures used during the project were developed to reduce time spent in the trap and handling time. Frequent removal of bobwhites from traps served to reduce self-inflicted trap-related injuries (trampling, head scalping, and wing scraping).

The main assumption needed for line transect sampling is that every individual bobwhite directly on the line walked by the observer is seen. If this assumption fails, the density estimate will be biased. This should not normally be a problem in that it is unlikely that an observer would literally walk over a healthy bobwhite.

Movement of coveys unseen by the observer could lead to an underestimate of density (Guthery 1988). Movement would manifest as higher frequencies of flushes in middle belts (distances) parallel to the transect line. Guthery (1988) concluded that this was rare based on research conducted in south Texas, and movement behavior did not seem apparent in my density estimates.

Censor Period

Analysis of survival curves provided at best a crude approximation of censor-period effects on estimates of survival. The survival curves and derivatives (Fig. 1) were subject to time-confounding. Accordingly, they were unbiased only if daily survival was constant from the date of first capture through the time required for the last bird captured to survive for 100 days. Seasonal effects on survival rates were evident in my analysis (Table 2), as well as in previous studies (Curtis et al 1988, Burger et al. 1995). Bobwhites captured earlier in the sample would have had winter months (Nov, Dec) within 100-day survival, whereas the birds captured later would have had spring months (Feb, Mar). The expectation would be for birds captured just prior to the winter months to experience lower survival than later-captured birds.

The results were ambiguous relative to the question of optimal censor period because a period ≥45 days appeared optimal in 2000–2001, whereas a 0-day censor period appeared optimal in 2001–2002. Undoubtedly, a larger dataset for analysis of censor-period effects is necessary to better understand censor effects on estimates of survival.

Nonetheless, these preliminary results provided some insights into the question of censor-period effects. First, although the sample was limited and time-confounded, no support was obtained for the widely used 7-day censor period. Second, the possibility exists that the optimal censor period depends on such matters as season and weather, so that general application of some fixed value may be inappropriate. Third, when recovery effects from capture and adjustment to transmitters occur, the effect may manifest as a trend rather than a threshold (Fig. 1B; days 20–45). If the effect is a trend, the appropriate censor period depends on properties of individual bobwhites, which change from area to area and time to time. Possible individual heterogeneity in censor periods provides further lack of support for general application of any fixed censor period because the average optimal censor period for any population will depend on the probability distribution of censor periods of individuals within the population.

The fixed censor period seems illogical for the reasons mentioned above. However, until the question of censor period has been addressed with a larger sample, biologists probably should continue to apply censor periods because in empirical cases a censor period is meritorious (Fig. 1B). However, the length of censor period to apply remains problematic. Generally, in modeling, when one makes an assumption the sensitivity of results to the assumption must be tested. With radio-telemetry data, the sensitivity of estimates of seasonal or annual survival to the censor period can be estimated by calculating the survival rate of interest under different censor periods (say periods of 0, 7, 14, and 21 days). If the estimates are similar, the censor period might be irrelevant. If the estimates differ, the highest estimated survival rate may provide the best approximation of survival in the population under study.

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Appendix 1. Monthly cause-specific mortality of northern bobwhites determined from telemetry data collected on the Mesa Vista Ranch, Roberts County, Texas, from 1 September 2000 to 31 May 2002.

			Mortality source					
Year	Period	n^a	Bird	Mammal	Hunt	Other	Censored	Survived
2000	1 Sep–1 Oct	6	0	0	0	1	0	5
	2 Oct–29 Oct	26	1	2	0	1	0	22
	30 Oct–26 Nov	28	4	0	0	0	0	24
	27 Nov–24 Dec	28	4	2	2	0	0	20
2001	25 Dec–21 Jan	31	3	6	0	0	1	22
	22 Jan–18 Feb	28	1	1	0	0	0	26
	19 Feb–18 Mar	31	4	2	1	0	0	24
	19 Mar–15 Apr	34	4	2	0	0	0	28
	16 Apr–13 May	39	1	6	0	0	3	29
	14 May–10 Jun	29	2	3	0	1	0	21
	11 Jun–8 Jul	21	1	1	0	0	1	19
	9 Jul–5 Aug	19	1	1	0	1	1	16
	6 Aug–2 Sep	16	1	1	0	0	1	13
	3 Sep–30 Sep	21	2	0	0	0	1	18
	1 Oct–28 Oct	40	1	1	0	1	2	35
	29 Oct–25 Nov	48	3	2	0	0	1	42
	26 Nov–23 Dec	43	1	3	0	1	1	37
2002	24 Dec–Jan 20	39	2	2	1	0	0	34

21 Jan–17 Feb	57	2	2	0	2	0	51
18 Feb–17 Mar	55	0	1	0	0	0	54
18 Mar–14 Apr	54	0	1	0	1	0	52
15 Apr–12 May	53	1	2	0	3	0	47
13 May–31 May	47	0	2	0	1	0	44

[a]Birds did not have to be at risk for the entire month.

Appendix 2. Frequency tables for cause of mortality for northern bobwhites used in calculation of *G* statistics, Mesa Vista Ranch Roberts County, Texas, 1 September 2000–7 January 2002.

Date		Cause of mortality			
Time class[a]	Period (days)	Bird	Mammal	Other	Total
1 Sep 2000–7 Jan 2001					
A	0–20	3	9	1	13
	21–40	6	1	1	8
	>40	11	12	3	26
B	0–14	3	6	1	10
	15–21	0	3	0	3
	>21	17	13	4	34
C	0–7	3	4	0	7
	8–21	0	5	1	6
	>21	17	13	4	34
1 Sep 2000–7 Jun 2001					
A	0–20	4	12	2	15
	21–40	7	6	2	15
	>40	21	17	5	43
B	0–14	4	9	1	14
	15–21	0	4	1	5
	>21	28	22	7	57
C	0–7	4	7	0	11

	8–21	0	6	2	8
	>21	28	22	7	57
13 Sep 2001–7 Jan 2002					
A	0–20	0	2	0	2
	21–40	1	2	0	3
	>40	5	6	5	16
B	0–14	0	1	0	1
	15–21	0	1	0	1
	>21	6	8	5	19
C	0–7	0	1	0	1
	8–21	0	1	0	1
	>21	6	8	5	19
1 Sep 2000–7 Jan 2002					
A	0–20	4	14	2	20
	21–40	8	8	2	18
	>40	26	23	10	59
B	0–14	4	10	1	15
	15–21	0	5	1	6
	>21	34	30	12	76
C	0–7	4	8	0	12
	8–21	0	7	1	8
	>21	34	30	13	77

[a]Refers to period classes given in the next column

VITA

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Candidate for the Degree of

Master of Science

Thesis: SURVIVAL, CAUSE-SPECIFIC MORTALITY, AND TELEMETRY EFFECTS ON NORTHERN BOBWHITES

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anterior system, responsible for executive functioning and performance of other complex tasks. These two systems involve different brain structures. The posterior attention system includes the superior parietal cortex, pulvinar, and superior colliculus. The anterior attention system includes the anterior cingulate cortex and basal ganglia (Posner & Dehaene, 1994).

Another neuropsychological approach recognizes three elements of attention namely, focus, sustain, and shift (Enns & Cameron, 1987; McKay, Halperin, Schwartz, & Sharma, 1994; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). Focus represents the ability to select a target for further processing. The sustain element represents the ability to maintain a focus or vigilance over time, and the shift element refers to the ability to change focus from one stimulus to another. An execute function should also be noted, which represents the behavioral response during attention. For the current study, the focus-execute and sustain elements are most important. Mirsky and colleagues (1991) proposed localization for these elements of attention based on electrophysiological and behavioral literature. They propose that the sustain element is represented within the brain stem area, while the focus-execute is represented within the posterior parietal areas. This idea is consistent with studies of parietal lesion patients who perform poorly on tasks of attention (Posner, Inhoff, Freidrick & Cohen, 1987). Not only is the parietal lobe important in visual selective attention, it is also vital to auditory selective attention. Patients with inferior parietal lesions can show auditory neglect to signals presented contralateral to the lesion (De Renzi, Gentilini, & Barbieri, 1989). Furthermore, parietal lobe lesion patients have difficulties disengaging attention from auditory cues presented contralaterally (Farah, Wong, Monheit, & Morrow, 1989). Additionally, neuroimaging studies have shown the cingulate cortex to be involved in attentional processing during visual dual-task situations (Posner & DiGirolamo, 2000) and appear to be especially important for target detection (Posner & Peterson, 1990).

These studies support the contention that at least some attentional functions are controlled by the parietal lobes (or posterior attention system). Research has also supported Posner and Dehaene's (1994) anterior system. Even though the frontal lobe is responsible for much more than cognitive ability, this is still the area of the brain that is assumed to house the executive functions, in particular, response inhibition (Barkley, 1997; Posner & DiGirolamo, 2000; Roberts & Pennington, 1996; Travis, 1998; van der Molen, 2000). If following the hypothesis that executive functions and attention are two different processes, and executive functions are primarily housed in the prefrontal cortex, Posner's anterior attention system may be a misnomer. Research supports a strong connection made between the frontal cortex and executive functioning (Roberts & Pennington, 1996; Travis, 1998; van der Molen, 2000), and the anterior attention system may better be addressed as the anterior executive system.

One such example of this confusion is seen in dual-task paradigms, which require the participant to perform two tasks at once, such as instructing a participant to press a button to a target word while counting all letters beginning with 'm'. This task most likely involves executive functioning, due to the working memory component, and may explain why Posner and DiGirolamo (2000) concluded that the anterior cingulate cortex (a component of the prefrontal cortex) is important in attention. In an auditory temporal processing study, adult participants were administered discrimination tasks that required a button press to a target stimulus or that required counting target stimuli (Pedersen, Mirz, Oversen, Ishizu, Johannsen, Madsen, & Gjedde, 2000). These researchers proposed both anterior and posterior attention systems due to the positron emission tomography (PET) results that showed activation of both frontal and parietal cortices to stimuli that required memorizing or attending as well as a deactivation of the posterior cingulate gyrus during "attention heavy" tasks. These tasks, however, involved attention, response inhibition, and working memory, thus tapping into both attention and executive functioning.

The skill and task most descriptive of executive functioning in the developmental studies reviewed earlier is response inhibition in selective attention situations. Selective attention tasks require an individual to attend and respond to a target or appropriate stimulus while ignoring inappropriate stimuli. Therefore, the person must inhibit responding to some non-target stimulus. Based on this idea, it is proposed that target detection utilizes posterior attentional systems for execution, while non-target inhibitory control utilizes frontal executive systems for execution. Therefore, the two systems may develop separately, one system developing more rapidly than the other. This idea would be consistent with Ridderinkhof and van der Molen (1995) who found developmental differences in response selection but not stimulus selection of young children.

Berger, Jones, Rothbart, and Posner (2000) may not agree with the idea of target detection controlled by posterior attentional systems. According to their research, three attentional networks have emerged within the literature and they describe each in relation to anatomical structures. The first system, *orienting*, is described as involving focusing attention, disengaging, and shifting attention and, is for the most part, localized in the posterior parietal lobes. The *vigilance* system is described as involving the maintenance of an alert state over time and involves the right parietal and right frontal cortices. Finally, the *executive* system involves goal-directed behavior and response inhibition, but also target and error detection, which is primarily located in the frontal region of the brain. Target detection is also described as a focus/execute system proposed by Mirsky et al. (1991). Contrary to Berger et al. (2000), Mirsky and colleagues would see this as a parietal function, not frontal.

Researchers seem to agree that different aspects of tasks used to measure attention involve very different brain areas, primarily the parietal and frontal lobes. The disagreement stems from understanding which of these task components is controlled by which brain area. The research supporting the response inhibition component being controlled by the frontal lobe is very convincing, however the attention (target detection/ignoring) component is not so explicitly categorized. Therefore, the neuropsychological literature does not provide the evidence to make a strong prediction of differential development.

Attention-Deficit Hyperactivity Disorder

Research and theory on Attention Deficit/Hyperactivity Disorder (ADHD) can also provide helpful insight into understanding the development of attention and response inhibition. Barkley (1996) developed a comprehensive model that describes the etiology of ADHD and impresses two important points. First, ADHD is most likely a developmental disorder in that children with ADHD fail to make appropriate developmental progressions in areas of cognitive development. Secondly, the primary cognitive deficit seen in children with ADHD involves deficits in executive skills, primarily response inhibition (with secondary problems developing in attention). The course of development of ADHD has shown that the problems with inhibitory control first arise around the ages of 3 or 4, while the problems related to attention arise around the ages of 5 to 7 (Hart, Lahey, Loeber, Applegate, Green, & Frick, 1996; Loeber, Green, Lahey, Christ, & Frick, 1992). That is, those children who undergo normal development begin to acquire response inhibition at about age 3 to 4, and attentional skills at about age 5 to 7, while ADHD children do not acquire these skills. The ADHD research would then suggest that the major improvement in development between the ages of 5 to 7 is an attentional change. Ridderinkhof and van der Molen (1995) would argue an improvement in inhibitory control during the 5-7 shift, while Bartgis et al. (2002) would say that both processes may be developing.

It is evident that previous research for the development of attention between the most crucial ages is lacking. The paradigms that have been utilized thus far are either confounded by tapping both attentional components and response inhibition, or fail to assess inhibitory processes all together. The present study follows the argument that response inhibition is the key to discriminating between attentional and executive functioning task components. Therefore, the purpose of this study was to differentiate between developmental improvements in attention and improvements in response inhibition for the 5-7 shift and to better define these constructs. An attempt was made to test attention alone, with only minimal inhibitory processes at work, by removing response competition and therefore the need to inhibit responding to irrelevant stimuli. Adding the need for response inhibition, then, assessed executive functioning. This can potentially present a clearer picture regarding developmental changes within this age range.

This study involved four phases. Phase 1 served as the baseline. In it, the 5- and 7-year-old participants heard 120 tones to which they were to press the space bar on a computer keyboard. In Phase 2, a cartoon was presented to attempt to distract the children's attention away from their primary task of responding to the target tones. Thus, in Phase 2 the children had to resist the distraction of the cartoon. However, no opportunity was provided for which they needed to inhibit the bar-press response. In Phase 3, a non-target tone was presented along with the target and the children were instructed not to respond to these non-target tones. No cartoon was presented. Thus, in Phase 3, children had to inhibit the bar-press response to the non-target tones. Here, their attention was not distracted away from the primary task. Indeed, in Phase 3, the children were required to focus their attention on the primary task domain in which two types of tones were being presented over their headphones. This focus on the primary task domain (i.e., listening for tones over the headphones) was the same for both Phase 1 and Phase 3. Phase 3, however, introduced a second stimulus into that task domain to which the children had to inhibit that same response that they were applying to the target tones. Thus, Phase 2 involved resisting being distracted away from the primary task domain, while Phase 3 involved maintaining attention to that task domain but resisting responding to certain stimuli within it. Phase 4 presented both the distracting cartoon and the non-target tone.

Three hypotheses were proposed for the current study. Hypothesis 1 states that the 5-7 shift involves improvement in attention. This hypothesis would be supported if children showed attentional improvement with age, but not inhibitory improvements. Hypothesis 1 would specifically involve improvement from ages 5 to 7 in the comparison of Phase 1 to Phase 2. Hypothesis 2 states that the 5-7 shift involves improvement in inhibitory skills. This hypothesis would be supported if children showed response inhibition improvement, but not attentional improvement. Hypothesis 2 would specifically involve improvement from ages 5 to 7 in Phase 3. Hypothesis 3 states that the 5-7 shift involves improvement in both processes. This hypothesis would be supported if children showed improvements in both attentional and inhibitory processes. Hypothesis 3 would specifically involve improvement from ages 5 to 7 in the comparison of Phase 1 to Phase 2 and Phase 3 of the study.

CHAPTER V

METHOD

Participants

A total of forty-three children were recruited from birth announcements that had been published in a local newspaper and through referrals from parents of participants in the project. The Developmental and Psychophysiology Laboratory has a file card system of birth announcements dating back more than 10 years and this allowed for recruitment of children ages 5- and 7-years. Of these 43 subjects, one child refused to give assent to participate in the study, one child was extremely fearful of the movie, and one child failed to meet the predetermined criteria, in that they continually made too many false alarms during practice session. Therefore, forty children, 20 in each of two age groups, were used in data analysis. The number of participants (N=40) was selected based on the effect size (.878) of a previous and similar study (Bartgis, McGee, & Thomas, 2002), and estimated power at .8 (see Appendix A). The two age groups ranged from 4 years, 11 months to 5 years, 10 months and 6 years, 11 months to 7 years, 10 months. Mean ages were 5.3 and 7.4 for each group. Each age group had 9 males and 11 females. The majority of the sample was Caucasian (92.5%), with ethnic minority children comprised of Native American (5%) and African American (2.5%). Participants were screened for neurological problems, auditory problems, learning disabilities, and attention disorders per parents' report. With the permission from the parent, participants were offered candy or a small toy for their participation following each of the first three phases.

Stimuli

Stimuli consisted of tones presented in a selective attention paradigm. The tones were presented over Optimus Nova-71 headphones while the subject was seated in front of a table that held a keyboard for the participants' responses. Located just behind the table was a television set up for viewing during testing. Stimuli were presented and heard in both ears simultaneously. Tones of 400 Hz (100ms) were designated as non-target tones while target tones were of 700 Hz (100ms). Four Phases were presented with random inter-stimulus intervals for all phases. Pilot testing determined the intensity of these stimuli.

In Phase 1, 120 target tones were presented. In Phase 2, 120 target tones were presented and a 4-minute segment of the movie video "A Bug's Life" was viewed on the television screen. In Phase 3, 120 target tones and 40 non-target tones were administered. Phase 4 consisted of 120 target tones, 40 non-target tones, and the video. In Phase 3 and 4, the overall probability of non-targets was .25 while the overall probability of targets was .75. Phases 3 and 4 had 160 tones at a random ISI with a mean of 1.5 seconds(s) and range of .8s to 2.2s. Phase 1 and 2 had ISIs identical to Phase 3 and 4, but 40 of the 160 tones were not presented. These trials were then called "silent blanks" rather than non-targets. If a response fell during this time it was called a silent alarm. Each phase lasted a total of 4 minutes. The four Phases were randomly counterbalanced using a Latin Square

Design. Each participant was randomly assigned to one of four possible Phase presentations: Phases 1, 2, 3, 4; Phases 2, 1, 4, 3; Phases 3, 4, 1, 2; and Phases 4, 3, 2, 1.

Phase 3 and 4 were an auditory variation of the Test of Variables of Attention (TOVA.). The TOVA is a visual task (there is also an auditory TOVA) that is often used for assessing ADHD and consists of target and non-target stimuli (Forbes, 1998). The TOVA is one of a number of Continuous Performance Tests (CPT's). In general, CPT's have adequate discriminate validity between ADHD and normal controls, but unfortunately do not discriminate between ADHD and other clinical groups (Anastopoulos & Shelton, 2001; Forbes, 1998; McGee, Clark, & Symons, 2000). The TOVA has demonstrated excellent internal stability (split-half), good temporary stability (test-retest) (Llorente, Amado, Voigt, Berretta, Fraley, Jensen, & Heird, 2001) and has better reported discriminate validity than the commonly used Conner's CPT's (Forbes, 1998; McGee et al., 2000).

In the visual TOVA, the target stimuli are represented by a large square box, with a smaller square box at the top of the larger one. The non-target stimuli are also represented by a large square box, but the smaller square box appears at the bottom of the larger one. One important component of the TOVA is the probability of targets and non-targets. The targets are the frequent stimuli, occurring 77.5% of the time, while the non-targets are the rare stimuli, occurring 22.5% of the time. This provides a high probability of errors of omission and errors of commission. Errors of omission are measured when the participant misses a target response (fails to respond when a response is appropriate). Omission errors are said to reflect inattention. Errors of commission are measured when the participant responds to a non-target. Commission errors are then said to reflect impulsivity or a lack of inhibitory skills (Forbes, 1998; Greenberg, 1991; Greenberg & Waldman, 1993). It should be noted that when comparisons are made between ADHD and other clinical groups, TOVA commission errors do not show statistically significant differences, but are in the expected direction with ADHD children showing more commission errors (Forbes, 1998). Developmental normative data on the TOVA indicate that younger children (6- to 7-years) display more commission errors when there is an increased target concentration, in that more targets are presented which increases the response demand (i.e., more responses must be made), than do older children (Greenberg & Waldman, 1993). One unpublished dissertation comparing ADHD and normal control groups on CPT's did find statistically significant differences on commission scores (Grooms, 1996).

Procedure

Upon entering the laboratory participants were given the first phase of the instruction in the form of a scripted story about an invisible rabbit that is stealing food from the laboratory (see Appendix B). The participant was seated in front of the keyboard and television with the headphones placed on the child's head. The headphones were described as a part of the special rabbit tracking gear, which allows the experimenter to monitor progress. The participants were instructed to press the space bar on the keyboard when they heard the "rabbit sound" (target). The practice trials then began.

Children underwent several practices. Prior to Phase 1 the practice session consisted of 12 target tones in which the participant responded to at least 9 out of 12 before proceeding to Phase 1. Phase 2 required the same practice (with 9 out of 12 target tones criteria) and further instructions informed the participant that a movie would be playing. Prior to Phase 3, several practice sessions were employed. The first practice session was identical to Phases 1 and 2 and required the child to respond to 9 of 12 target tones. The second practice session presented both targets (rabbit sound) and non-targets (which were described as the sound of the guard) and required a child to respond to at least 9 out of 12 targets and no more than 1 of 4 non-targets before preceding to the phase. Phase 4 required the same practice sessions as Phase 3 and the additional instructions that informed the participant that a movie would be playing. The first practice session of 12 targets was given in Phases 3 and 4 only when one of these phases was the first condition the child received.

All practice criteria had to be met before proceeding. If the child did not meet the predetermined criteria for any given practice session, the instructions and practice session was re-administered until the child met criteria or through four practice sessions. One child exceeded four practice sessions without meeting criteria and was excluded from the study. Additionally, children received a prize for "working hard" following the first three Phases presented. The child was taken upstairs to collect the prize to break up the monotony of the task with an attempt to address boredom or fatigue.

CHAPTER VI

RESULTS

Each child's data consisted of number of correct responses to target tones in each phase ("hits"); reaction times for hits; number of incorrect responses to non-target tones in Phases 3 and 4 ("false alarms"); reaction time for false alarms; and the number of responses that intruded into the silent blanks intervals in Phases 1 and 2 ("silent alarms"). Manipulation checks were performed to ensure that the task was serving the intended purpose. To examine the film's ability to serve as a distraction for a child's correct responses, a manipulation check was performed on the hits measure for Phase 1 and Phase 2 by age. Presenting the film (Phase 2) resulted in significantly fewer correct responses to target stimuli (hits) than did the baseline phase (Phase1) for 5-year-olds, F (1, 39) = 105.12, $p < .0001$, and for 7-year-olds, F (1, 39) = 40.86, $p < .0001$. Therefore the film appears to have served as an appropriate distraction for both age groups. To examine the ability of the non-target stimuli to provoke the need to inhibit responding, a manipulation check was performed for Phase 1 and Phase 3 by age. Using the non-target stimuli to measure inhibitory skills resulted in significantly more false alarms in Phase 3 than silent alarms in Phase 1 for 5-year-olds, F (1, 39) = 14.23, $p = .001$, and for 7-year-olds, F (1, 39) = 11.02, $p = .002$. Therefore the non-target tone appears to have served as an adequate provocation for children in both age groups and required a need to inhibit responding.

Hypotheses were tested using planned comparisons. Phase 1 was used as a baseline in which to measure attention relative to Phase 2, which had an added level of extraneous distraction. The first hypothesis stated that the 5-7 shift involves improvement in attention. This would be supported if the two groups differ between Phase 1 and Phase 2, and 7-year-olds perform more accurately (more hits) than 5-year-olds. Alternatively, both age groups could exhibit similar responding rates (hits), which would indicate that 5- and 7-year-olds do not differ in their attentional abilities required for the tasks presented here. Although possible, it was not anticipated that 5-year-olds would outperform 7-year-olds on any of these phases. To ensure that both age groups were equivalent at the baseline phase, a t-test was conducted comparing the mean number of hits between the two age groups (see Figure 1, Appendix C). The t-test indicated that 7-year-olds had significantly more correct hits in their performance at baseline than did 5-year-olds, $\underline{t}$ (38) = 2.127, $\underline{p}$ = .04, two-tailed. Therefore the analysis conducted to measure attentional improvement used the baseline measure as a covariate. A one-way analysis of covariance (ANCOVA) was conducted examining the number of hits in Phase 2 with age as the between-subjects factor, and hits on Phase 1 as the covariate. This analysis resulted in significantly better performance for 7-year-olds over 5-year-olds, $\underline{F}$ (1, 39) = 5.66, $\underline{p}$ = .023, with observed power of .64 and Partial Eta-Squared of .34 (see Figure 2, Appendix C). Therefore, analysis of the first hypothesis showed attentional improvements between the ages of 5 and 7. This finding was also supported by an ANCOVA that examined the number of hits in Phase 4 with each age group. The hits measure appears to be sensitive to the effects of the film. Therefore, hits in Phase 4 can provide additional support for the effect of the film on children's performance (the effect of the non-target on children's performance will be discussed later). This ANCOVA examined the number of hits on Phase 4 with age and hits on Phase 1 as the covariate, which resulted in significantly better performance for the 7-year-olds as compared to the 5-year-olds, $\underline{F}$ (1, 39) = 12.31, $\underline{p}$ = .001, with observed power at .93 and Partial Eta-Squared at .25.

Two-way analyses of variance were also used to assess the effects of the film on performance of the task. All two-way analyses used in this study are similar to the one-way analyses, except that the focus is on the interaction to see if one group changed more than the other across phases. To determine the effect that the film had on the primary task, a two-way ANOVA was conducted that measured the number of hits in Phase 3 as compared to the number of hits in Phase 4 for both age groups. This analysis resulted in a significant age main effect, $\underline{F}$ (1, 39) = 15.43, $\underline{p}$ = .0001 (observed power of .97 and Partial Eta-Squared of .29), with 7-year-olds making more correct hits than 5-year-olds, and a significant film effect, $\underline{F}$ (1, 39) = 140.68, $\underline{p}$ = .0001 (observed power of 1.0 and Partial Eta-Squared of .79), with the introduction of the film decreasing correct hit rate for both age groups. Additionally there was a significant age by film interaction with 5-year-olds showing a more dramatic decrease in number of correct hits in Phase 4 than 7-year-olds, $\underline{F}$ (1, 39) = 8.91, $\underline{p}$ = .005 (observed power of .83 and Partial Eta-Squared of .19) (see Figure 3, Appendix C).

Phase 1 was also used as a baseline in which to measure errors to non-targets against Phase 3. Phase 1 was administered by random ISI and therefore presented silent blanks in place of non-target tones presented in Phase 3. The total number of errors can be compared by examining the child's silent alarms to silent blanks in Phase 1 to the child's errors to non-target tones in Phase 3 (see Figure 4, Appendix C). Hypothesis 2 stated that the 5-7 shift involves improvement in inhibitory skills. Similar to hypothesis one, these phases were expected to show that 5- and 7-year-olds made the same number of errors to non-targets, which would support the hypothesis that response inhibition skills do not differ between these age groups, or to show that 7-year-olds make fewer errors to non-targets than 5-year-olds, which would indicate that 7-year-olds have better response inhibition skills. To ensure that both age groups were equivalent at the baseline phase, a t-test was conducted comparing the means of ages on the silent alarm measure at Phase 1. The t-test indicated that there were no differences between age groups in their silent alarm rate at baseline, $t\ (38) = .358$, $p = .72$, two-tailed. Therefore the analysis conducted to measure response inhibition improvements did not require the use of the baseline measure as a covariate. A one-way analysis of variance (ANOVA) was conducted examining the number of false alarms in Phase 3 with each age group and resulted in no differences between age groups, $F\ (1, 39) = 1.28$, $p = .265$, with observed power at .2 and Partial Eta-Squared at .007. This finding was supported by a follow-up analysis that examined the number of false alarms in Phase 4 with each age group, which again resulted in no significant differences between age groups, $F\ (1, 39) = 3.51$, $p = .069$, with observed power at .45 and Partial Eta-Squared at .09.

A two-way ANOVA was conducted to measure the number of silent alarms (blanks) in Phase 1 as compared to the number of false alarms in Phase 3 for both age groups. As would be expected from the planned comparisons, this analysis resulted in no significant age effect (observed power of .16 and Partial Eta-Squared of .02), but a significant tone effect, $F\ (1, 39) = 25.14$, $p = .0001$ (observed power of 1.0 and Partial Eta-Squared of .40), with the introduction of the non-target tone increasing the number of false alarms for both age groups. More importantly, no significant age by tone interaction existed, F (1, 39) = .10, p = .751 (observed power of .05 and Partial Eta-Squared of .003) (see Figure 5, Appendix C). This same analysis was conducted comparing the silent alarms in Phase 2 with the false alarms in Phase 4 and resulted in a similar finding of no age effect, F (1, 39) = 3.53, p = .068 (observed power of .45 and Partial Eta-Squared of .09), but a significant tone effect, F (1, 39) = 19.82, p = .0001 (observed power of .99 and Partial Eta-Squared of .34), with the introduction of the non-target tone in Phase 4 increasing the number of false alarms for both age groups. However, again no significant interaction existed, F (1, 39) = 3.53, p = .068 (observed power of .04 and Partial Eta-Squared of .001).

Similar to examining the effect of the non-target tone on children's performance, false alarm rates can be used to examine the effect of the film on performance. A comparison of the number of silent alarms in Phase 1 as compared to the number of silent alarms in Phase 2 for both age groups was also conducted to examine the impact of the addition of the film to the non-target tone. This two-way ANOVA resulted in no effect of age on the number of silent alarms, F (1, 39) = .25, p = .619 (observed power of .05 and Partial Eta-Squared of .007), no effect of film on the number of silent alarms, F (1, 39) = 2.12, p = .154 (observed power of .29 and Partial Eta-Squared of .05), and no age by film interaction, F (1, 39) = .94, p = .338 (observed power of .17 and Partial Eta-Squared of .02). Additionally, the number of false alarms in Phase 3 was compared to the number of false alarms in Phase 4 for both age groups. This analysis resulted in no age main effect, with 5- and 7-year-olds making similar false alarm rates overall, F (1, 39) = .18, p = .671 (observed power of .05 and Partial Eta-Squared of .005), but the introduction of the film in Phase 4 resulting in more false alarms for both age groups, F (1, 39) = 5.80, p = .021 (observed power of .65 and Partial Eta-Squared of .13). Additionally there was a significant age by film interaction with 7-year-olds responding to more false alarms in Phase 4, F (1, 39) = 10.61, p = .002 (observed power of .89 and Partial Eta-Squared of .22) as compared to 5-year-olds (see Figure 6, Appendix C).

To determine the effect that the non-target tone had on the primary task of responding to the target tone, a two-way ANOVA was conducted on the number of hits in Phase 1 as compared to the number of hits in Phase 3 for both age groups. This analysis resulted in a significant age main effect, F (1, 39) = 5.06, p = .030 (observed power of .59 and Partial Eta-Squared of .12), with 7-year-olds making more correct hits than 5-year-olds, and a significant tone effect, F (1, 39) = 64.49, p = .0001 (observed power of 1.0 and Partial Eta-Squared of .63), with the introduction of the non-target tone decreasing correct hit rate for both age groups. No significant age by tone interaction existed, F (1, 39) = .00, p = .959 (observed power of .037 and Partial Eta-Squared of .0001) (see Figure 7, Appendix C). However, a one-way ANCOVA was conducted to examine the number of hits in Phase 3 for both groups. When baseline differences between groups were covaried out the age effect was not longer found, F (1, 39) = .50, p = .485 (observed power of .115 and Partial Eta-Squared of .013).

The impact of the non-target tone on the primary task can also be determined by comparing the number of hits in Phase 2 to the number of hits in Phase 4, which resulted in a similar finding that 7-year-olds making more correct hits than 5-year-olds for both phases, F (1, 39) = 17.59, p = .0001 (observed power of .98 and Partial Eta-Squared of .31), and the introduction of the non-target tone resulting in a decrease in number of correct hits for both age groups, F (1, 39) = 9.38, p = .004 (observed power of .85 and Partial Eta-Squared of .20) (see Figure 8, Appendix C). Again, no significant age by tone interaction existed, F (1, 39) = .01, p = .936 (observed power of .038 and Partial Eta-Squared of .0001). In examining the hits in Phase 1 compared to the hits in Phase 3, and the hits in Phase 2 as compared to the hits in Phase 4, the non-target tone appeared to disrupt performance for both age groups, with 5-year-olds being more impacted by the non-target tone. As reported earlier, when accounting for age differences at baseline for the hits measure in Phase 3 this age effect drops out, F (1, 39) = .50, p = .485. However, when both non-target and film are present in Phase 4, accounting for age differences at baseline does not impact the significance level and 7-year-olds still make more correct hits than 5-year-olds, F (1, 39) = 12.31, p = .001.

Following testing of the hypotheses, exploratory analyses were conducted on the response time data. Plotted histograms indicated that the response time data were positively skewed. Therefore a logarithmic transformation was performed on each child's reaction time data. All analyses were conducted on transformed data. To ensure that both age groups were equivalent at the baseline phase, a t-test was conducted comparing the mean hit reaction time between the two age groups. The t-test indicated that 7-year-olds had significantly faster reaction time at baseline than did 5-year-olds, t (38) = 3.501, p = .001, two-tailed (see Figure 9, Appendix C). Therefore the analyses conducted to measure response time for hits used the baseline measure as a covariate. A two-way ANCOVA was conducted examining three levels of phase (Phases 2, 3, and 4) by age with hit reaction time for Phase 1 entered as the covariate. The results of this analysis found no effect of age (observed power of .05 and Partial Eta-Squared of .005), but a significant

CHAPTER VII

DISCUSSION

In an attempt to disentangle the constructs of attention and response inhibition, a paradigm was designed to measure these as independently as possible. The results of this study showed that 7-year-olds were less distracted by the film and made significantly more correct hits in their performance at Phase 2 (with the baseline phase covaried) than did 5-year-olds. However, when measuring inhibitory ability by the number of false alarms in Phase 3, the results showed no significant differences between groups. Therefore, the results of this study support cognitive changes in the 5-7 shift involving only attentional improvements, not inhibitory improvements. Additionally, the results indicate that attention and response inhibition are separate constructs that develop independently. The results for both the accuracy and response time data will be discussed and an attempt made to address potential alternative responses. Implications for interpreting previous research will also be addressed and a Developmental Delay Model for ADHD will be described.

Accuracy Data

To ensure that the tasks were measuring the constructs they were designed to measure, manipulation checks were performed. Within each age group, children had significantly fewer hit responses on the attention task in Phase 2 as compared to baseline.

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Accuracy Data

To ensure that the tasks were measuring the constructs they were designed to measure, manipulation checks were performed. Within each age group, children had significantly fewer hit responses on the attention task in Phase 2 as compared to baseline.

This supports the contention that the film served as an appropriate distraction for both age groups, thus supporting Phase 2 as an adequate measure of attention. Another manipulation check for the response inhibition task indicated that within each group, children made significantly more false alarms at Phase 3 as compared to baseline. Therefore the non-target tone appears to have served as a stimulus that required response inhibition for children in both age groups. An examination of the effect of the non-target tones on children's false alarm performance compared the changes from Phase 1 to Phase 3 and from Phase 2 to Phase 4. These comparisons resulted in significantly more false alarms with the introduction of the non-target tone for both age groups, above and beyond the unintentional silent alarms. This finding is additional support for the impact of the non-target tone to provide provocation for children in both age groups that required the need to inhibit responding, thus supporting Phase 3 as an adequate measure of response inhibition.

There are two ways to address the primary questions of attentional improvement with the four phases, namely examination of hits and examination of false alarms. When assessing the impact of the film, or the attention measure as defined in this study, several comparisons can be made. As noted, the Phase 2 hits measure resulted in a significant difference between groups, with 7-year-olds outperforming 5-year-olds. This difference was significant even after holding age differences at baseline constant. This finding is consistent with the results of the Phase 4 hit measure that also resulted in significant differences between groups.

Another way to examine the effect of the introduction of the film was to measure the change from Phase 3 to Phase 4 on the hits measure. This comparison describes the effect of the addition of the film on children's performance and allows for examination of interactions. Again, there was a large effect of the film for hits from Phase 3 to Phase 4, just as there was for hits from Phase 1 to Phase 2, but here we have an interaction effect (see Figure 3, Appendix C). The film appears to be overwhelming for 5-year-olds and results in a dramatic decrease in number of correct hits. This overpowering effect of the film can be described in terms of stimulus overload for the 5-year-olds in that their performance is impacted both in correctness of selection and number of overall responses. This stimulus overload may represent the inability of 5-year-olds to avoid overall distraction and to allocate attention to the primary task of responding to the target tones. Seven-year-olds, on the other hand, appeared to be less influenced by the film as evidenced by more correct hits.

The second way to address the primary question of attention improvement is with the examination of false alarms and silent alarms. When examining the change in silent alarm rate between Phases 1 and 2, no significant differences were found for age or phase. This indicates that the addition of the film did not impact the silent alarm rate for either age group. The effect of the film can also be examined by comparing the changes in false alarm rate between Phases 3 and 4. This comparison of false alarm rate from Phase 3 to Phase 4 resulted in a significant age by film interaction, in that when both the film and the non-target tone were present in Phase 4, the 7-year-olds increased the number of false alarms over what they had in Phase 3, while the 5-year-olds' false alarm rate remained constant (see Figure 6, Appendix C). This is consistent with the analysis of the hit measure in that 5-year-olds were so negatively impacted by the attention task that when the film was presented in addition to the non-target tone, 5-year-olds lost attention to the primary task and made fewer responses overall. Seven-year-olds then, made more false alarms because they were paying more attention in general and making more responses.

Most of the results in the current study were in the expected direction with the exception of the Phase 4 false alarm rate for each group. The finding that 7-year-olds made more errors than 5-year-olds on false alarms in Phase 4 was not hypothesized and was in direct opposition to what would be expected based on developmental norms. This finding was described as an overload for 5-year-olds in that they stopped paying attention to the primary task, which resulted in fewer responses overall, while 7-year-olds were making more false alarms because they were not as effected by the attention task and were paying more attention in general. Alternative explanations for this finding include the idea that there is something about 7-year-olds cognitive development that impacts their ability to perform with stimulus "overload." However, when examining the hit rate on Phase 4, seven-year-olds significantly outperformed five-year-olds, even when age differences at baseline were held constant. If there was something about the additive effect of film and non-target presentation in Phase 4 that affected performance rate, it seems as though this would impact performance on hits as well as false alarms for 7-year-olds. This was not the case.

Additionally, this unexpected finding could be hypothesized to occur because 7-year-olds were really more accurate in responding, but that they were just responding late to target tones, which increased their number of observed false alarms. This also seems to be incorrect as 7-year-olds had a slower mean response time in Phase 4 as compared to Phase 3, indicating that they were not responding late to a previous tone. If 7-year-olds had been responding late to previous target tones, their response times on the false alarms would have been very fast; instead, it was slower. Therefore, it appears as though this unanticipated finding can be described as stimulus overload for 5-year-olds, resulting in fewer responses, and enhanced attentional abilities for 7-year-olds, resulting in more responses in general and thus, more errors.

Response inhibition improvement can also be addressed in two ways by examining both hits and false alarms in the four phases. As previously stated, examining the false alarms in Phase 3 resulted in no significant differences between age groups. This analysis supports the contention that the cognitive improvement seen in children ages 5 to 7 does not appear to involve the development of response inhibition skills.

Another way to examine the effect of the introduction of the response inhibition task is to measure the change from Phase 1 to Phase 3 and Phase 2 to Phase 4 on the false alarm measure for each age. These comparisons described the effect of the addition of the non-target tone on children's performance and allowed for examination of interactions. The comparisons produced a phase effect but no effect of age or age by phase interactions. This indicates that the introduction of the non-target tone produced significant numbers of false alarms equally in both age groups, above and beyond the unintentional silent alarms.

Finally, the hits measure can also provide some insight into the development of response inhibition. Examining the changes from Phase 1 to Phase 3 and from Phase 2 to Phase 4 on the hits measure can determine the impact of the addition of the non-target tone on hit rate. These comparisons resulted in significant age main effects with 5-year-olds making fewer correct hits than 7-year-olds in all phases. There was also a significant phase effect in each of these comparisons, which suggests that the addition of the non-target tone (in Phase 4 and over and above the film in Phase 2 and in Phase 3 over and above the baseline phase) resulted in poorer hit performance for both age groups. This indicates that the non-target tone not only impacted the alarm performance for both groups (more false alarms than silent alarms) but it also impacted the hit rate with 5-year-olds making fewer correct hits than 7-year-olds. However, these analyses were conducted without using the baseline phase as a covariate, and therefore age differences were not accounted for. Furthermore, although a significant decrease in hit performance (especially for 5-year-olds) was observed when assessing the impact of the non-target tone, this significance was not as great as the impact of the film. The change from baseline to Phase 3 resulted in an overall reduction of 11.2% for five-year-olds and 10.5% for seven-year-olds, while the change from baseline to Phase 2 resulted in a reduction of 38.7% and 22.5% for the two age groups. So although the non-target tone resulted in fewer correct hits for all children, the magnitude of this finding is small as compared to the impact of the film.

Overall, accuracy data measuring cognitive improvement in the 5-7 age shift indicate that 7-year-olds are better able to resist distraction than 5-year-olds, thus demonstrating an improvement in attentional abilities across the age span. The cognitive changes in the 5-7 shift do not appear to involve improvement in response inhibition as 5- and 7-year-olds had similar false alarm rates. Consequently, it is concluded that, because the accuracy data support these skills developing differentially, that they must represent separate constructs.

Reaction Time Data

The reaction time data indicate that 5-year-olds had significantly slower response times than did 7-year-olds at baseline on hits measures. Therefore, analyses conducted used Phase 1 hit reaction time as a covariate to account for *a priori* age differences. The overall analysis for the hits measure showed that both age groups had slower response times when both the film and the non-target tone were present (Phase 4) than seen in either Phase 2 or 3. This difference was present even when the age differences in response time were held constant (Phase 1 covariate). This is further support for the idea that Phase 4 presents "stimulus overload" that impacts both reaction accuracy and reaction time. However, the phases did not differentially affect each age group after age differences at baseline were accounted for. This is in contrast to the accuracy data finding that the most difficult phases (Phase 2 and 4) resulted in poorer hit performance for 5-year-olds over 7-year-olds.

Analysis of false alarm reaction time in phases 3 and 4 also used Phase 1 hit reaction time as a covariate because this latter measure was seen as an accurate assessment of the simple reaction time of each age group. The overall analysis for the false alarm measure resulted in a significant phase effect, with all children displaying slower response times at Phase 4 as compared to Phase 3. Again, no age differences were found. So, although the phases impacted the response times, with Phase 4 presenting the most difficulty for children on hit and false alarm measures, age did not appear to be a significant factor once baseline differences were accounted for.

Implications for Previous Research

Lane and Pearson (1982), as reviewed earlier, proposed that the developmental improvement seen in attention might involve encoding, stimulus selection, or response selection. Both Ridderinkhof and van der Molen (1995) and Bartgis, McGee, and Thomas (2002) attempted to support the above model in differing ways, both utilizing physiological and behavioral measures in selective attention tasks. Ridderinkhof and van der Molen concluded that response selection, not stimulus selection, was responsible for the 5-7 shift, while Bartgis, McGee, and Thomas concluded that both stimulus selection and response selection were responsible for the 5-7 shift. The current study serves to integrate information available from Bartgis and colleagues (2002) and Ridderinkhof and van der Molen (1995), demonstrating that the ability to select a stimulus (stimulus selection) improves between the ages of 5-7. This stimulus selection improvement appears to be descriptive of changes in attentional, not inhibitory, abilities. That is, older children are better able to select a stimulus that exists with some overall level of distraction. However, older children do not improve in their ability to select an appropriate response (i.e., a non-response to stimuli that are highly competitive). Additionally, if the response inhibition task in the present study was too easy and therefore did not differentiate groups (see discussion of this point below), the attention task still showed differences, which would also challenge the findings of Ridderinkhof and van der Molen. Therefore, this study would lend support to stimulus selection improvements in the 5-7 shift, at least from a behavioral standpoint.

Alternative Explanations

To address potential alternative explanations for findings, it is important to start by examining the utility of the tasks. Critics could examine these tasks and question whether or not they were truly measuring those constructs they were intended to measure. Primarily, Phase 3 in the study could be described as another attention task or selective attention task rather than a task tapping into response inhibition skills. However, if Phase 3 were just another attention task that tapped the same mechanisms as Phase 2, then the results should have shown an age difference similar to those found with Phase 2. Seven-year-olds were performing significantly better on the attention task (more correct hits) in Phase 2, even after age differences were accounted for, but on Phase 3 no hit differences were found. The distinction between Phases 2 and 3 are the film that served as a distraction for attention and the non-target tone that required immediate inhibition of responses. Therefore it appears that the tasks were measuring different constructs, and the constructs appear to be separate, developing independently.

The paradigm used here to measure attention and response inhibition was modeled after a continuous performance test (CPT), the Test of Variables of Attention (TOVA). CPT's are criticized in the literature for issues related to discriminate validity and reliability of the measures. CPT's were primarily designed to track medication effects, but later became a relatively standard component in a battery for ADHD assessment. Studies of discriminate validity reported in the literature examined ADHD children as compared to other clinical groups. One important study (Forbes, 1998) identified a cutoff score on the TOVA that would enhance the ability to detect children with ADHD versus those with other clinical problems. This cutoff score of 1.5 standard deviations above the mean on any one variable, except commission errors, resulted in 80% of the ADHD group being correctly identified (positive finding on the TOVA) versus 72% of the other clinical group being correctly identified (negative finding). This results in one of the lowest overall false positive/false negative rates that have been identified on CPT's. Therefore, the clinical utility of the TOVA when used in a battery of tests for ADHD assessment is quite good, and displays adequate discriminate validity when used in this way.

Continuous Performance Tests, TOVA included, have also been criticized for the commission errors score not holding up under statistical analyses. When discriminating between samples of clinical populations the commission errors do not result in statistically different scores. This is seen primarily with ADHD versus other clinical groups. Little is known about the difference of scores between ADHD and normal control groups as only one unpublished study was identified and much of what presents to a clinical setting is a clinical population that must be correctly identified. Furthermore, the only normative data available for the TOVA assessed children ages 6 to 16 and although the investigators found age differences, they grouped 6- and 7-year-olds together and they did not use younger children in their sample (Greenberg & Waldman, 1993).

When comparisons are made between ADHD and other clinical groups, the failure of commission errors to result in statistically significant differences may be a result of the few numbers of commission errors in general. When examining means of commission errors they are always in the expected direction with ADHD groups scoring slightly higher (more errors) than other clinical groups. There are a number of childhood disorders (namely, Conduct Disorder, Oppositional Defiant Disorder, and some children with various severity levels of Mental Retardation) (Diagnostic and Statistical Manual for Mental Disorders, 4th Edition [DSM-IV], 1994) that also evidence problems with response inhibition, which may impact the poor discriminate validity on commission errors for clinical populations. This problem with commission errors could impress the interpretation of the results of the current study. A result of no differences could be interpreted as an inability to detect a difference if one exists due to an ineffective measure. However, the one unpublished study reviewed (Grooms, 1996) examining the within-test variability for omission and commission scores for the TOVA, compared ADHD and normal controls and found statistically significant differences on errors of commission between groups and homogenous test variance within groups. This would indicate that the potency of detecting differences on the commission measure within the TOVA is adequate when comparing normal and ADHD populations. Therefore, it would appear that the primary problem with commission errors is discriminating ADHD and other clinical groups, not ADHD and normal groups. Given that the Groom study found consistency within ADHD and normal groups and that the normative data show differences between groups (for children ages 6-16) (Greenberg & Waldman, 1993), it would appear that the TOVA is appropriate for measuring response inhibition by commission scores. This can lend support to the non-significant findings between age groups on the Phase 3 false alarm measure in that the paradigm is based on the TOVA, which appears to be appropriate for detecting differences if they exist.

Developmental Delay Model for ADHD

The results of the current study also provide some support for theory and research in the area of Attention-Deficit/Hyperactivity Disorder (ADHD). Barkley (1996) proposed that ADHD is a developmental disorder and that the primary deficit involves executive functions, particularly response inhibition. The developmental trajectory of ADHD has shown that problems with inhibitory control arise around age 3 to 4 years, while the secondary problems related to attention arise around age 5 to 7 years (Hart et al., 1996). The current research allows extrapolation to normal children. We would assume that children with normal development would begin to acquire response inhibition skills around age 3 to 4 years if Barkley identifies problems with response inhibition for children with ADHD developing during this age range. Additionally, we would assume attentional skills to develop around age 5 to 7 years, as this is the age span in which Barkley describes problems with inattention emerging for ADHD children. The current study found attentional improvement between the ages of 5 and 7 years, but not improvement in inhibitory control. If children with ADHD are displaying problems with attentional skills between the ages of 5 and 7 years, then normal developing children should not evidence these same problems and, in essence, should acquire these skills during this time, if ADHD is truly a developmental disorder. Because the current study showed attentional improvement in normal development between the ages of 5 and 7, it lends support to Barkley's model of ADHD in that attention (or inattention for ADHD children) develops within the 5-7 shift, and we would argue a Developmental Delay Model for children exhibiting ADHD.

The theory that ADHD is a severe developmental delay can explain both neuropsychological and developmental changes seen in childhood. In examining the neuropsychological development of ADHD, children would be seen as failing to normally develop certain brain functions. Children at age 3 begin to maintain control over their behaviors more so than their younger counterparts. So a 3-year-old with normal development may not be able to stop himself from hitting his little sister in his parents' presence to avoid punishment, but a 4- or 5-year-old could likely inhibit this behavior. Where a 3-year-old may run and climb excessively, a 5-year-old slows down and does not display as much impulsivity. Five-year-olds will be able to participate in a short conversation with an adult without responding or reacting to everything in their environment. This slowing down could involve fear of punishment, a need to maintain social rules, or just a general biological "slowing" that results from increased inhibitory skills. Research would suggest that this behavioral development includes simultaneous development of certain brain structures. Posner's work (Posner & Dehaene, 1994; Posner & Peterson, 1990) would support simultaneous development of the anterior cingulate and other structures related to the prefrontal cortex with the behavioral inhibitory improvement seen in early childhood. A Developmental Delay Model of ADHD, then, would posit that children who develop ADHD would fail to develop these behavioral skills as well as the appropriate prefrontal lobe activity associated with those skills.

The normal cognitive development of attention would also coincide with simultaneous brain development. However, as seen from previous research, this brain development may not be definitively supported in the literature. Where a 5-year-old may have difficulty attending to lengthy instructions or a short lecture on addition and subtraction, a 7-year-old would have the ability to attend without losing all train of thought. The main crux of research would suggest that these behavioral abilities would concur with parietal lobe development (Posner & Dehaene, 1994; Posner & Peterson, 1990), but, again, this literature is not thoroughly convincing. A Developmental Delay Model of ADHD would assume that children with ADHD would fail to develop attentional skills and their associated neurological functions.

This developmental delay model is further supported by neuroimaging and electrical waveform studies examining young children with ADHD that have found deficits in a number of brain structures and functions. These studies used samples with a mean age of 10 and a range from 6-14 years, so they do not examine children in very early childhood. Klorman (1991) provided an overview of early Event-Related Potential (ERP) studies examining differences between children diagnosed with ADHD and normal controls. Klorman concluded that there were deficits in both behavioral and physiological measures. Children with ADHD had fewer correct hits and more errors to non-target stimuli than did normal controls on selective attention tasks. Also, the reaction times of ADHD children were slower and more variable. The physiological measures discussed in this review included P3b amplitude (theoretically measuring amount of processing), P3b latency, and a negative difference waveform (Nd). ADHD children performing the CPT had smaller P3b amplitudes for both targets and non-targets as well as slower P3b latency than normal controls. Studies on Nd resulted in smaller negativity (difference between the attended target and non-target tones on selective attention tasks) for ADHD children relative to normals. Jonkman and colleagues (Jonkman, Kemner, Verbaten, Koelega, Camfferman, Gaag, Buitelaar, & Engeland, 1997a; 1997b) measured both auditory and visual selective attention in a study that lends support to Klorman's overview. They tested ADHD children and normal controls, ages 7-13, and found that ADHD children had fewer correct hits, more false alarms, and smaller P3b amplitudes than normals. The results of these studies suggest that ADHD children have poorer behavioral performance on tasks that require both a response to target stimuli and a non-response (inhibition) to non-target stimuli. Furthermore, the ERP data suggest that ADHD children process stimuli to a lesser extent, and are slower in processing stimuli than normal controls. The Nd data also suggest that ADHD children process both targets and non-targets similarly, thus displaying a deficit in the ability to discriminate stimuli. These neurological "deficits" as described in children with ADHD have also been found in what is considered "normal" development of younger children without ADHD.

Magnetic Resonance Imaging (MRI) studies have also found differences between ADHD children and normal controls. ADHD children have shown significantly smaller posterior corpus callosum regions of the brain than do normal functioning children (Semrud-Clikeman, Filipek, Biederman, Steingard, Kennedy, Renshaw, & Bekken, 1994) and more symmetric anterior brain regions (Hynd, Semrud-Clikeman, Lory, Novey, Eliopulous, & Lyytinen, 1991). Studies using computerized tomography (CT) and MRI have found some evidence of brain abnormalities in the frontal cortex, and have reported consistency on structural and functional studies, indicating impairment in the frontosubcortical system of ADHD children (Faraone & Biederman, 1998).

Although most studies indicate both behavioral and processing deficits in ADHD children, the ERP evidence is inconsistent in the literature (Miller, Kavcic, & Leslie, 1996; Taylor, Sunohara, Khan, & Malone, 1997). A more recent study (Taylor et al.,

1997) failed to find differences in P3 amplitude or behavioral data, but did note differences on P3 latency. ADHD children had faster latencies than normal controls on a serial selective attention task. These researchers concluded that ADHD children had "automatic" rather than "controlled" processing; an idea that is consistent with response inhibition deficits. Clearly, previous research has noted impairments in both behavioral responses and cognitive processing in children with ADHD. At this time the literature needs amalgamation as well as more studies examining younger children.

Although there are discrepancies in the neuropsychological literature of ADHD, there seems to be enough evidence to support a Developmental Delay Model. The model proposed in this paper supports the notion that older children with ADHD will have similarities to younger children without ADHD in both behavioral responding and brain processing on attention and response inhibition tasks. Proposed similarities for ADHD children and younger normal children include poor behavioral performance on measures of attention and response inhibition, smaller P3 amplitudes, and smaller Nd waveforms as compared to same-age peers of ADHD children. The literature is so divergent with regard to latency of processing and response time that an educated prediction at this point could not be made. It seems as though children with ADHD would display faster response times and faster P3 latencies because of the problems with response inhibition, but if they are also having problems related to attention, these speeds may be delayed. Research already suggests some of the proposed similarities exist. Klorman's review (1991) suggests that ADHD children with a mean age of 10 make fewer correct hits, more errors, have smaller Nd waveforms, and smaller P3 amplitudes to both target and non-target stimuli than normal controls on selective attention tasks. Bartgis, McGee, and Thomas

(2002) found that normal 5-year-olds showed fewer hits, more errors, smaller Nd amplitude, and no differences in P3 amplitude between attended and ignored channels (indicating that 5-year-olds were processing both channels equivalently) as compared to older children. These striking similarities on performance of 10-year-old ADHD children and 5-year-old normal children as compared to 9- to 10-year-old normal children may be more than coincidental and support a Development Delay Model of ADHD. It is therefore proposed that ADHD is a developmental delay and that the behavioral performance and ERP qualities of a 5-year-old without ADHD would be similar to the performance of an older child with ADHD. This model would argue that there exist critical periods in early childhood development in which normal children acquire certain skills that occur simultaneously with the maturation of corresponding brain structures and functions. ADHD children, on the other hand, do not develop these skills at the same rate as normals, and also evidence brain abnormalities. The developmental literature would suggest that these critical periods would be around 3-4 and 5-7 years of age. Research is needed to test this theory and would require comparisons of normal children and ADHD children across various ages.

Strengths and Weaknesses

The current study is the first known that attempts to disentangle two very important constructs that are continuously confounded in the literature. The results of this study can have direct implications for both normal and abnormal childhood development. However, there are a few weaknesses that should be addressed. First of all, it is plausible that the current study failed to find differences between age groups on the response inhibition measure because the task was not taxing enough. However, if this response inhibition task was too simple and did not tax children's abilities, then there should not have been a substantial increase in the number of commission errors from Phase 1 to Phase 3. In fact, the error rate from Phase 1 to Phase 3 more than doubled (15.2% to 35.5%).

Additionally, the Bartgis, McGee, and Thomas (2002) study found that 7-year-olds were superior both on making more correct hits and on making fewer errors. The current study only found improvement in the number of correct hits, showing then that the 5- and 7-year-olds made an equal number of false alarms. Again, these results could indicate that the current paradigm was not difficult enough to detect differences. However, the percentages of overall errors seen in the Bartgis et al. study (12.5%), where significant effects were found, were smaller than the overall error rate in the current study (28.7%). Therefore, it appears as though the current paradigm provided ample opportunity to commit false alarms, and thus to detect a difference between ages, if one existed.

To better understand the difference in outcome of these studies, one must also explain the primary difference between these two studies. The current study presented tones to both ears (a single channel), while Bartgis and colleagues (2002) presented a tone to either the left ear or the right ear (two channels). In Bartgis and colleague's study, children heard stimuli in both ears, one ear being the relevant channel, and the other being the irrelevant. Two types of tones were presented, the target tone and the standard tone, each of which could occur in either ear. Children were instructed to respond to targets in the relevant channel and to ignore targets in the irrelevant channel as well as all standards. When a child responded to a target tone in the irrelevant channel, it would surely indicate a shift in attention away from the relevant channel, however it was not a shift away from the relevant tone. Attention was still being allocated to the same tone, but not the same channel. Furthermore, when a child responded to a standard tone in the relevant channel, it would not be a shift in attention from the relevant channel, however it would be a shift away from the relevant tone. In this instance, attention was still being allocated to the same channel, but not the same tone. The Bartgis et al. paradigm represents a true "selective attention task", but presents some confusion when determining constructs measured.

Examining the paradigm of the current study, when a child responded to a non-target tone, it does not mean a shift in attention away from the target or relevant channel. Attention is still being allocated to the same channel because there is only one channel in which both target and non-target tones are presented. When a non-target tone is presented then, it is not a shift in attention, but an evaluation of the stimulus to determine if further resources need to be expended (i.e., if a response should be made). A child's response to a non-target tone in the current study is very similar to a response to the standard tone in the attended ear in Bartgis et al. (2002) study. The current study found high response rates to the non-target tone (38% for 5-year-olds and 33% for 7-year-olds) but found no significant differences. The Bartgis et al. study found significant differences in the standard false alarm rate, but the rates were lower (11% for 5-year-olds and 2% for 7-year-olds) which may be of questionable validity.

The potential criticism that the current study failed to detect differences because the paradigm was not taxing enough, or that it was not measuring children's inhibitory abilities, is unlikely. First of all, the significant increase seen in false alarm rates from Phase 1 to Phase 3, indicate that the non-target tone impacted inhibitory processes for all children. Second, the Bartgis, McGee, and Thomas (2002) study found age differences in false alarm rates and had lower overall false alarm rates than did the current study. Finally, given that the target and non-target tone occur in the same channel for the current study, a response to the non-target tone does not represent a shift in attention, but rather a poor response decision (poor inhibition). Overall, it appears that Phase 3 in the present study, sufficiently taxed children's inhibitory abilities and the non-significant finding implies that children's ability to select a response does not improve within the 5-7 shift.

Another way to address the discrepancies found between these two studies is to critically analyze the results and conclusions made by Bartgis, McGee, and Thomas (2002). Bartgis and colleagues found that 7-year-olds made fewer errors than 5-year-olds, both on responses to targets in the unattended channel and responses to standards in the attended channel. Furthermore, the ERP responses for 5-year-olds' showed P3 waveforms that were large in both channels, whereas 7-year-olds' showed larger P3 amplitudes to the attended channel over the ignored. So, it may be that 7-year-olds were not better at selecting a response (response selection) in the Bartgis et al. study, but rather selecting a stimulus (stimulus selection). Therefore, the increase in errors to targets in the unattended channel and the increase in errors to standards in the attended channel for 5-year-olds, may have been due to problems with stimulus selection not response selection as concluded in that study.

Finally, it is important to critically examine the Developmental Delay Model of ADHD that was presented in the current paper. The model attempts to provide a way of understanding ADHD and incorporates the developmental trajectory and neurological impairment observed in the disorder. However, this model is not saying that all normal children have ADHD and eventually "grow out" of it, or will continue to live a life with symptomotology. This model would argue that there are critical periods in childhood development in which normal children acquire certain skills and the development of related brain structures, while ADHD children do not develop these skills at the same rate and also evidence brain abnormalities. Furthermore, the current study examines a very limited aspect of the Developmental Delay Model of ADHD and it would be important to investigate all the constructs and related tasks associated with the disorder.

Summary

The current study provides a clear argument for the idea that resisting distraction (attention) and resisting responding (response inhibition) are separate constructs. Also, this paper describes the cognitive improvements in the 5-7 shift as involving attentional change. The results provide insight into the neuropsychological literature as well as the ADHD literature, and stimulate more questions about these areas of discipline. Furthermore, this paper provides a rationale for a Developmental Delay Model of ADHD.

This study has attempted to define attention and response inhibition and test these two constructs individually. Phase 1 of the study allowed a baseline measure of attention and had embedded within it "silent alarms" which permitted a comparison for a true measure of response inhibition when assessing "false alarms" in Phase 3. This measure showed no differences between groups, thus failing to show inhibitory improvements in the 5-7 shift. The comparison between the correct hits in Phase 1 and hits in Phase 2 allowed a valid measure of attention. This comparison revealed differences between groups, demonstrating behavioral superiority of 7-year-olds over 5-year-olds. The study concluded that the improvements noted throughout the literature in the 5-7 shift represent attention, not response inhibition.

The current study also provides a source of information for the field of cognitive research in that attention and response inhibition were "separated" and measured independently. Because there appear to be improvements in attention, but not response inhibition, it can be concluded that these processes are not a part of the same construct. Rather, attention and response inhibition represent different constructs that develop independently of one another. This also resonates to the neuropsychological literature. These two constructs that are developing independently most likely are represented in different regions of the brain. Two systems have been proposed by Posner and colleagues (Posner & Dehaene, 1994; Posner & Peterson, 1990) and are supported throughout the literature: the anterior attention (or executive) system that represents response inhibition and involves prefrontal regions, and the posterior attentional system that represents attention, namely target detection.

The Developmental Delay Model of ADHD posits that children with ADHD fail to develop certain behavioral skills as well as certain brain structures that correspond to those skills. The model proposes that older children with ADHD will have similarities to younger children without ADHD in both behavioral responding and brain processing. This idea is supported by research that has found similar behavioral and physiological data when comparing younger and older children, and when comparing children with and without ADHD (Bartgis, McGee, & Thomas, 2002; Klorman, 1991; Jonkman et al., 1997). These data appear to support the notion that ADHD is a developmental delay and would propose that brain maturation in normal children results in acquisition of certain skills, whereas there is a failure of appropriate brain maturation in children with ADHD, thus resulting in behavioral skills deficits. Barkley (1997) has already described ADHD in terms of a developmental disorder and has illustrated the developmental trajectory of ADHD. The current study supports Barkley's model of ADHD by showing attentional improvement between the ages of 5-7, the age in which Barkley proposes a breakdown in attentional abilities for children with ADHD. He argues that critical periods exist in which children's behavioral symptoms of ADHD emerge, with behavioral inhibition deficits emerging at age 3-4 and inattention at age 5-7. The Developmental Delay Model of ADHD would describe behavioral improvements in normal children as resulting from brain maturation and behavioral deficits in children with ADHD as resulting from brain delays in these processes.

In order to test a Developmental Delay Model of ADHD, research would need to compare normal children and ADHD children across various ages using the current paradigm to measure attention and response inhibition, constructs proposed to be deficient in children with ADHD. Furthermore, it would be important to look at other constructs and related tasks associated with the disorder. Research on a Developmental Delay Model of ADHD would provide information for both normal and abnormal development, as well as information regarding cognitive and neuropsychological advancement. Other research should examine the inconsistencies in the neuropsychological literature with attempts to further integrate this field of study.

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APPENDIXES

APPENDIX A

POWER ANALYSIS FOR

ANOVA DESIGN

The power parameters you specified were:

- a = '2' (levels of factor for power)
- b = '2' (levels of factor(s) crossed with A)
- delta = '.878' (effect size(s))
- alpha = '0.05' (significance level)

```
Power analysis for ANOVA designs
Sample size to achive a given power, alpha= 0.05

---------------
|       |DELTA|
|       |-----|
|       |0.878|
|-------+-----|
|Power  |     |
|-------|     |
|0.5    |    6|
|-------+-----|
|0.6    |    7|
|-------+-----|
|0.7    |    9|
|-------+-----|
|0.8    |   12|
|-------+-----|
|0.9    |   16|
---------------
```

The sample size values given are those for each of the 2 levels of the factor called 'Factor A'.With 2 combinations of other factors at each level of Factor A, divide the sample size by 2 to determine the sample size per treatment cell.
friendly@yorku.ca

APPENDIX B

SCRIPT FOR CONDITIONS

Introduction for each Session:

I've invited you here today because we have an invisible rabbit that steals food here in our laboratory. Do you know what invisible means? *(allow the child to answer or provide an answer)*. We've tried very hard to catch the rabbit but we can't so, we decided to get some help. We hired an invisible guard to catch the rabbit but he says the rabbit is too smart and he still needs more help. So, I called your parents and asked if you could come help us today. Would you mind helping us out?

Good! Because you are going to do your best and *work hard* to help us catch the rabbit you will get to pick out goodies from the goody sack. Okay! Now, to be able to catch the rabbit you've got to be able to hear him right? Well, we have special headphones which will help you to hear when the rabbit tries to steal the food. I'm going to let you hear what the rabbit sounds like and I want you to practice pushing the button when you hear the rabbit sound.

<u>Target Only</u>
Now you will hear the rabbit sound many times. So you need to push the button as quickly as you can every time you hear the rabbit sound. Okay? Ready to Practice?

PRACTICE- Must meet criteria * *(10 of 12 target tones)*

Good Job! Remember to push the button as fast as you can every time you hear the rabbit sound. Let's do it for real now. *Begin Condition***

<u>Target + Film</u>
Now you will hear the rabbit sound many times. So you need to push the button as quickly as you can every time you hear the rabbit sound. Okay? Ready to Practice?

PRACTICE- Must meet criteria * *(10 of 12 target tones)*

Good Job! I'm going to turn a movie on for you to watch while you try to catch the rabbit. Remember to push the button as fast as you can every time you hear the rabbit sound. Let's do it for real now. *Begin Condition* **

<u>Target + Distractor Tone</u>
Now you will hear the rabbit sound many times. So you need to push the button as quickly as you can every time you hear the rabbit sound. Okay? Ready to Practice?

PRACTICE- Must meet criteria * *(10 of 12 target tones)*

Good Job!
Now you know what the rabbit sounds like, this is another sound you will hear. It's the sound of the guard (PLAY NON-TARGET). Remember that the guard is on our side and he's trying to keep the rabbit away from the food too. So, when you hear the guard sound (PLAY NON-TARGET) you don't push the button or you don't do anything, Ok? Now let's listen so you'll know what the guard sounds like (PLAY NON-TARGET). What do you do when you hear the guard sound? That's right, you just listen.

PRACTICE- Just listen to the guard

Now, let's try them together. What do you do when you hear the rabbit? What do you do when you hear the guard? That's right! Now here is the rabbit sound (PLAY TARGET) and here is the guard sound (PLAY NON-TARGET). Let's practice!

PRACTICE- Must meet criteria * ***(10 of 12 targets and no more than 1 of 4 distractors)***

Good Job! Remember to push the button as fast as you can every time you hear the rabbit sound. Let's do it for real now. *Begin Condition* **

Target + Distractor Tone + Film

Now you will hear the rabbit sound many times. So you need to push the button as quickly as you can every time you hear the rabbit sound. Okay? Ready to Practice?

PRACTICE- Must meet criteria * ***(10 of 12 target tones)***

Good Job!

Now you know what the rabbit sounds like, this is another sound (PLAY NON-TARGET) you will hear. It's the sound of the guard. Remember that the guard is on our side and he's trying to keep the rabbit away from the food too. So, when you hear the guard sound (PLAY NON-TARGET) you don't push the button or you don't do anything, Ok? Now let's listen so you'll know what the guard sounds like (PLAY NON-TARGET). What do you do when you hear the guard sound? That's right, you just listen.

PRACTICE- Just listen to the guard

Now, let's try them together. What do you do when you hear the rabbit (play target) ? What do you do when you hear the guard (PLAY NON-TARGET)? That's right! Now here is the rabbit sound (PLAY TARGET) and here is the guard sound (PLAY NON-TARGET). Let's practice!

PRACTICE- Must meet criteria * ***(10 of 12 targets and no more than 1 of 4 distractors)***

Good Job! I'm going to turn this movie on for you to watch while you try to catch the rabbit. Remember to push the button as fast as you can every time you hear the rabbit sound. Let's do it for real now. *Begin Condition* **

*If child does not meet criteria, go back over directions and try practice again. You can do this up to 3 times until they meet criteria.

**BREAK between each condition. When the child returns from break, remind them that they will get another surprise for trying to catch the rabbit again. Only present a break and reminder for the first 3 phases.

Only present highlighted area (during Phase 3 or 4) when this is the first Phase presented in the series.

Note to Experimenter:

-Remember to remind children to push the button to the "rabbit sound" after 20 trials and then 40 trials have been presented.

- If necessary, remind subject to look at the TV screen during all Phases (especially Phase 1 and 3).

APPENDIX C

FIGURES

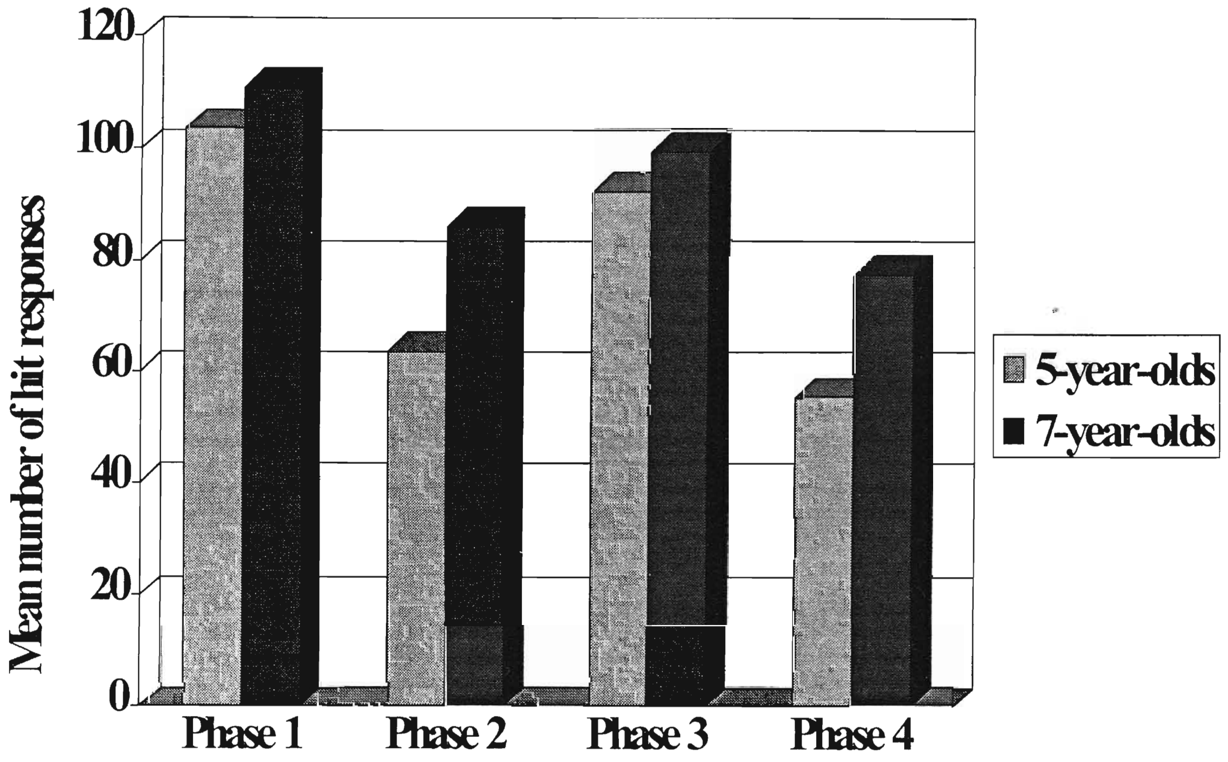

Figure 1. Mean Number of Hit Responses For Each Age Group and in Each Phase.

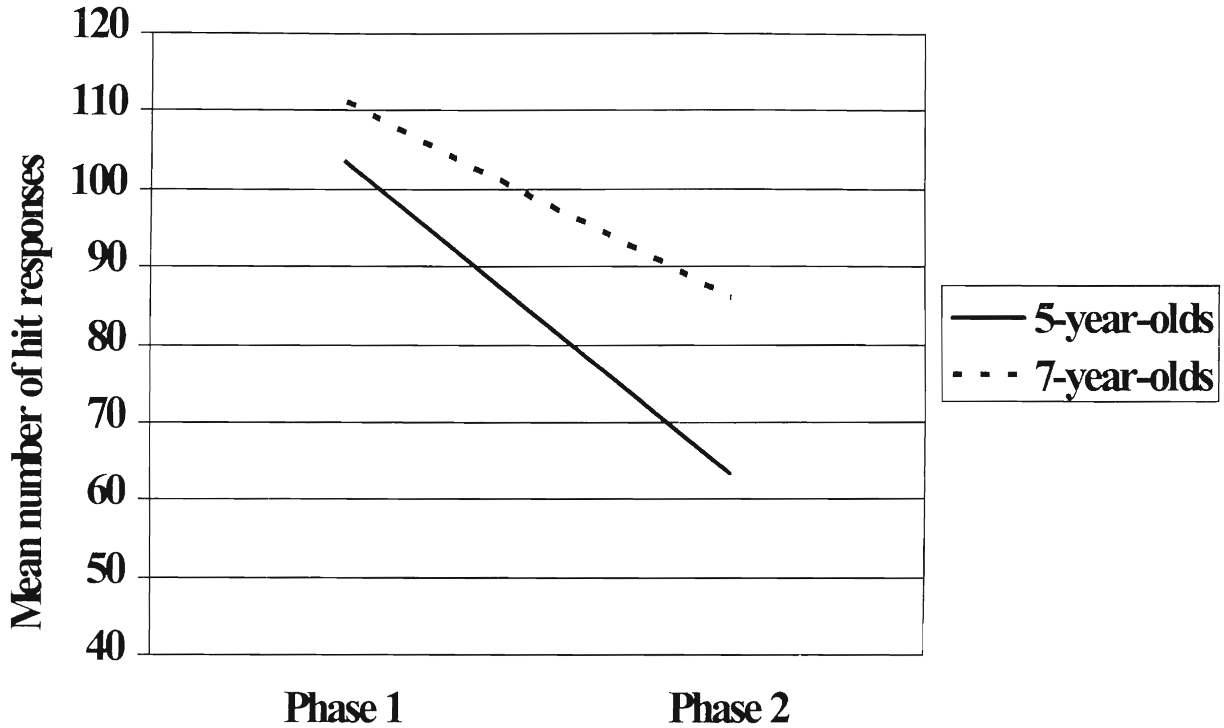

Figure 2. Mean Number of Hit Responses in Phases 1 and 2 For Each Age Group

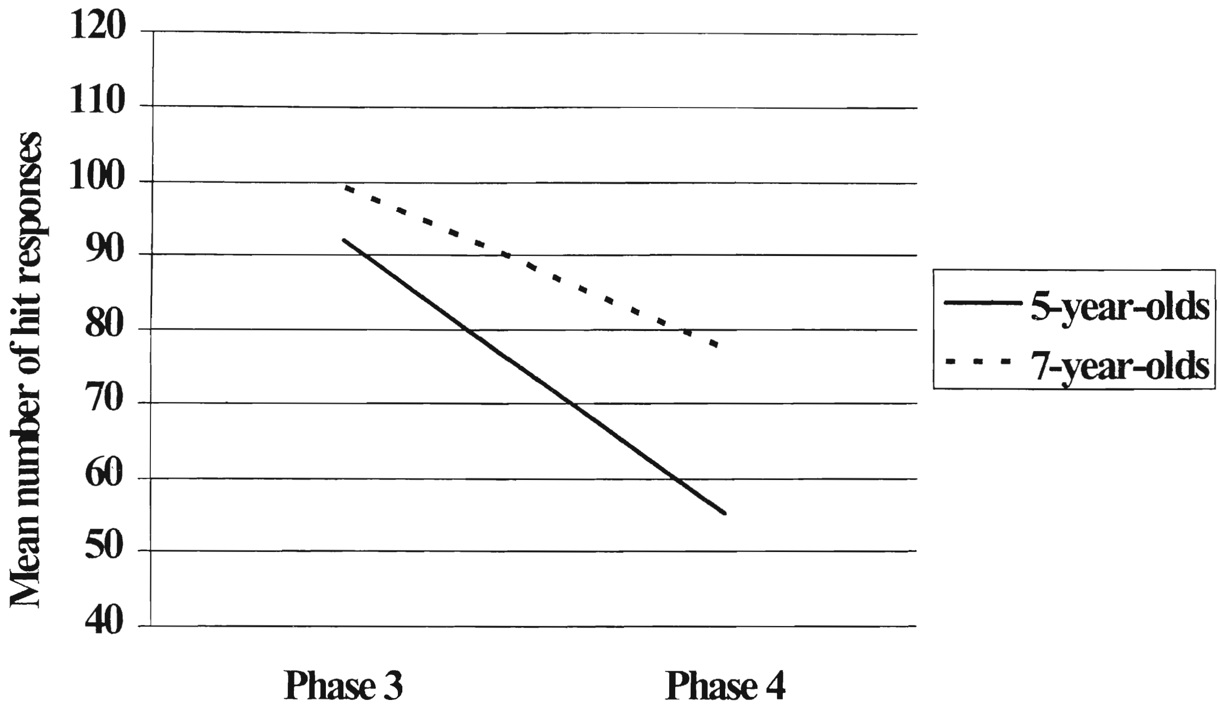

Figure 3. Mean Number of Hit Responses in Phases 3 and 4 For Each Age Group

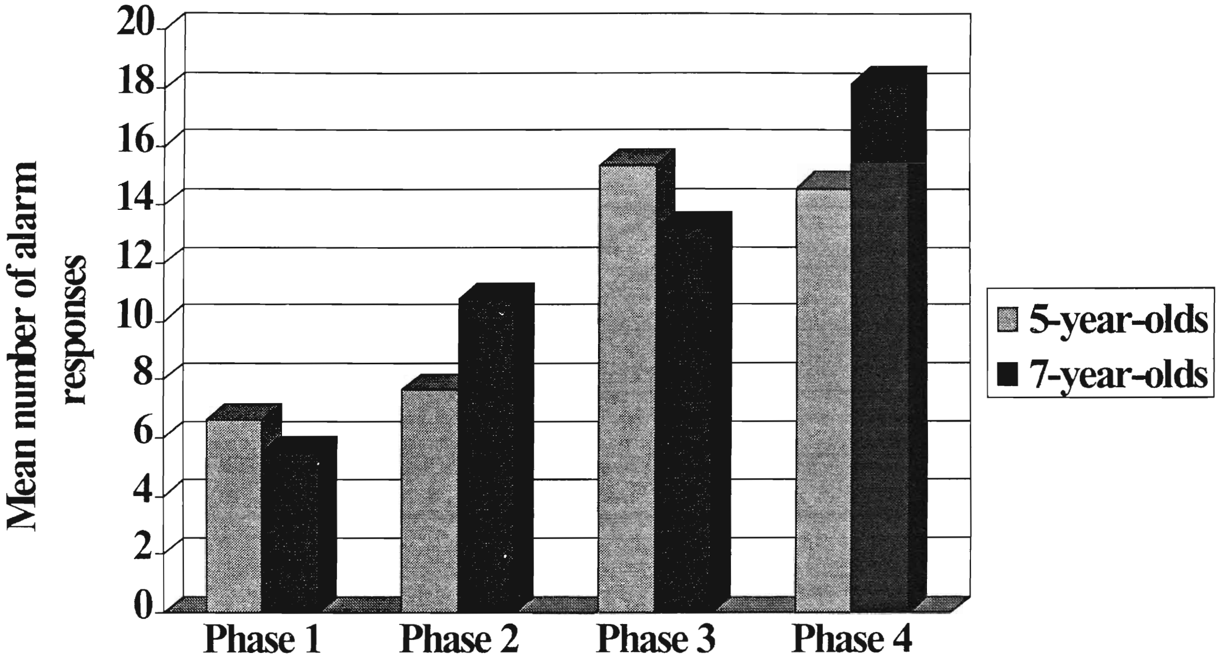

Figure 4. Mean Number of Silent Alarms in Phases 1 and 2 and Mean Number of False Alarms in Phases 3 and 4 For Each Age Group

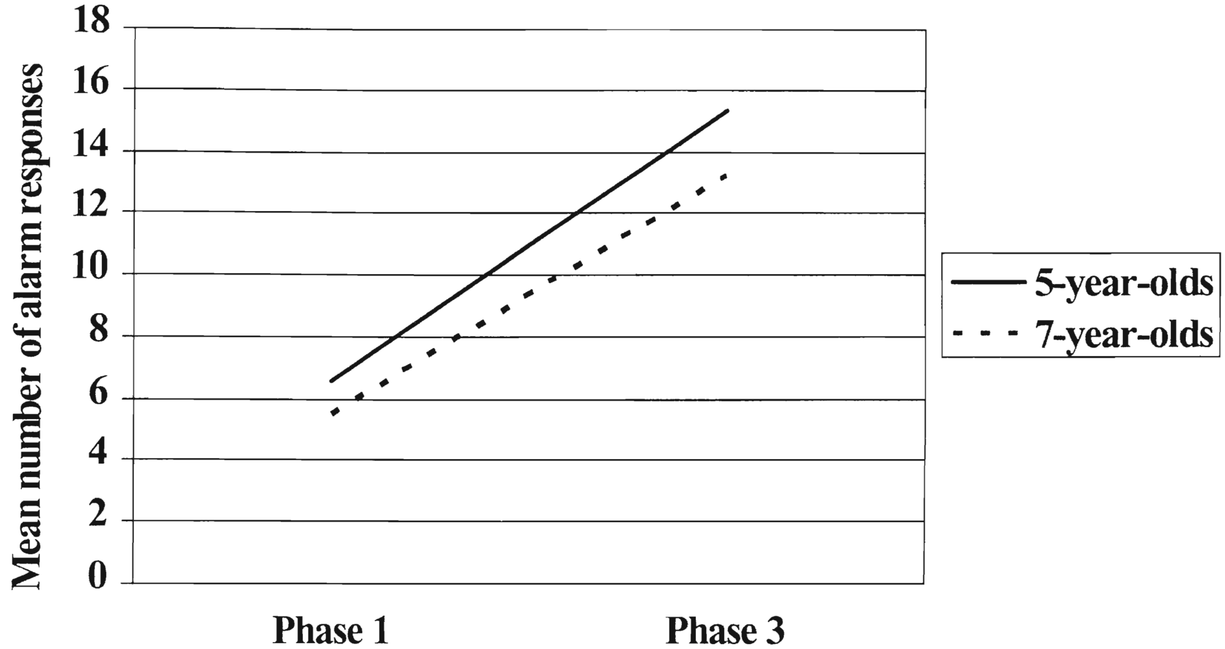

Figure 5. Mean Number of Silent Alarm Responses in Phase 1 and the Mean Number of False Alarm Responses in Phase 3 For Each Age Group.

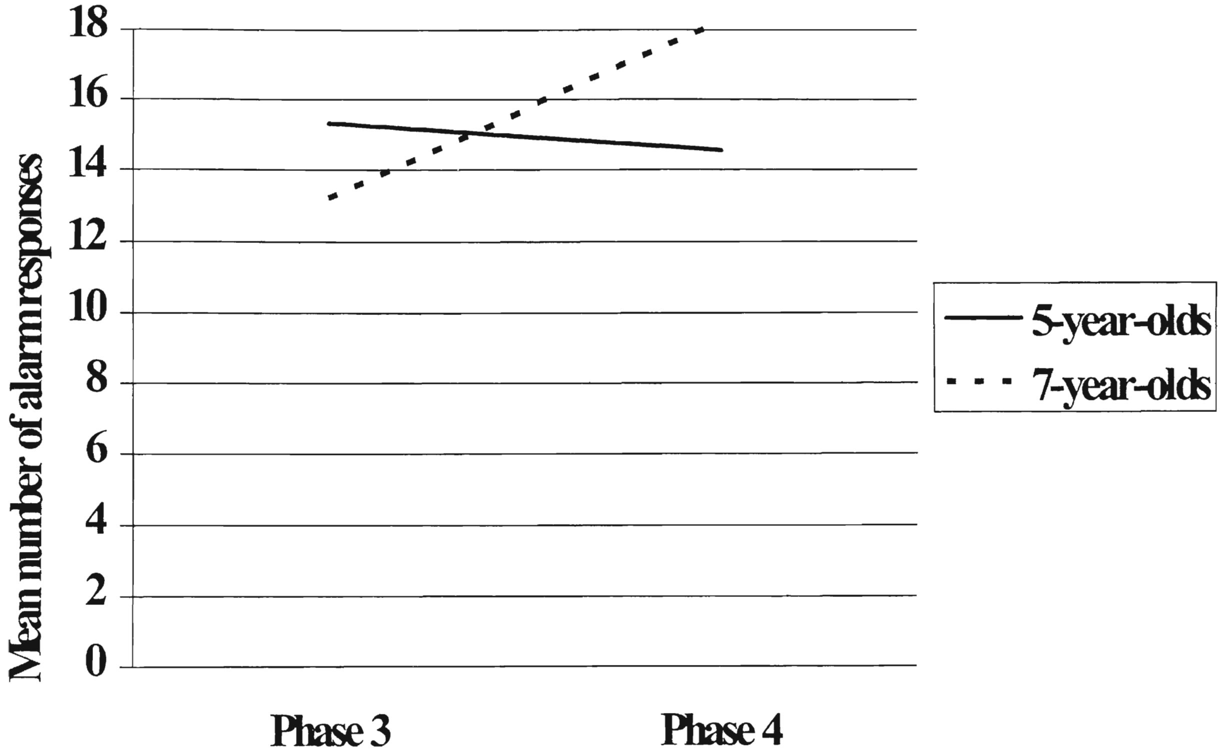

Figure 6. Mean Number of False Alarm Responses in Phases 1 and 3 For Each Age Group

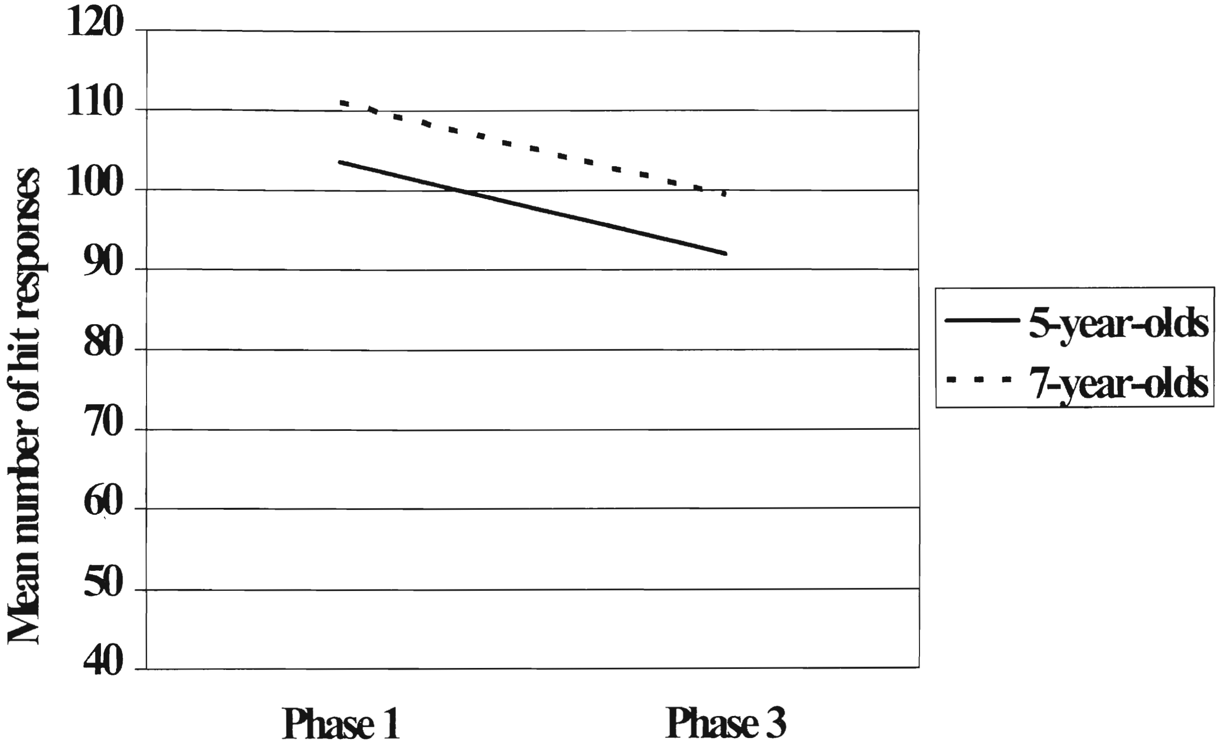

Figure 7. Mean Number of Hit Responses in Phases 1 and 3 For Each Age Group

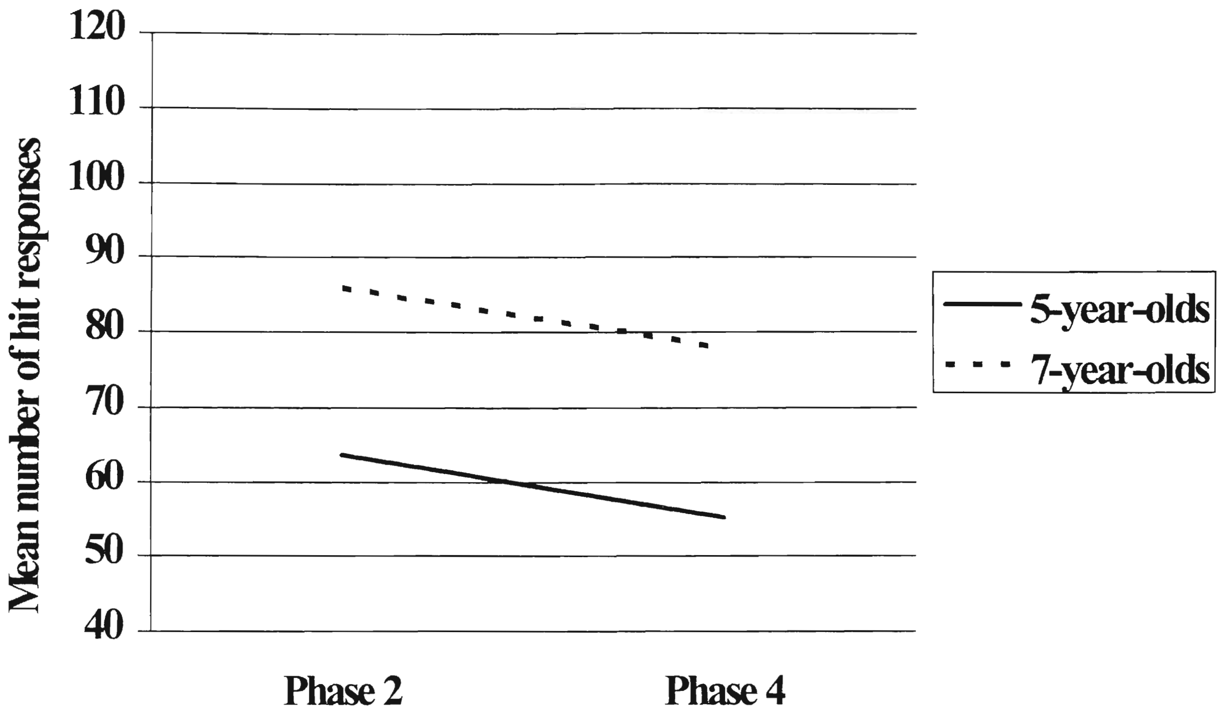

Figure 8. Mean Number of Hit Responses in Phases 2 and 4 For Each Age Group

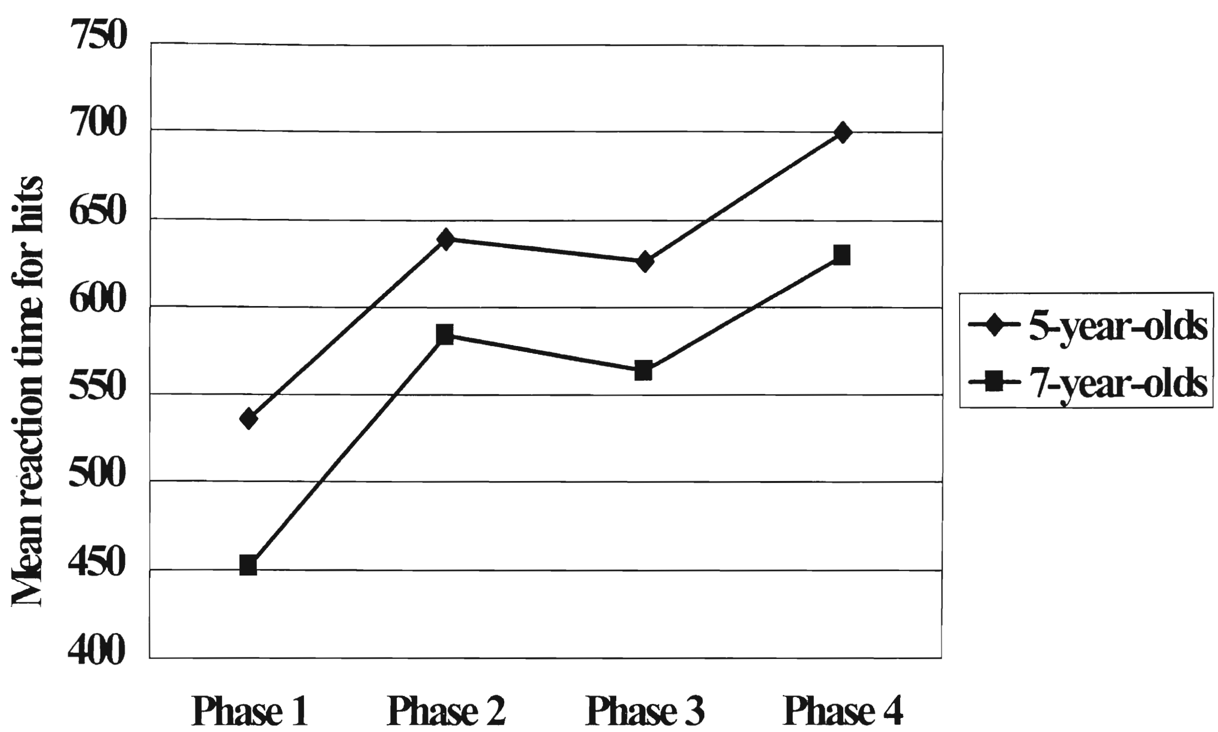

Figure 9. Mean Reaction Time for Hits For Each Age Group and in Each Phase

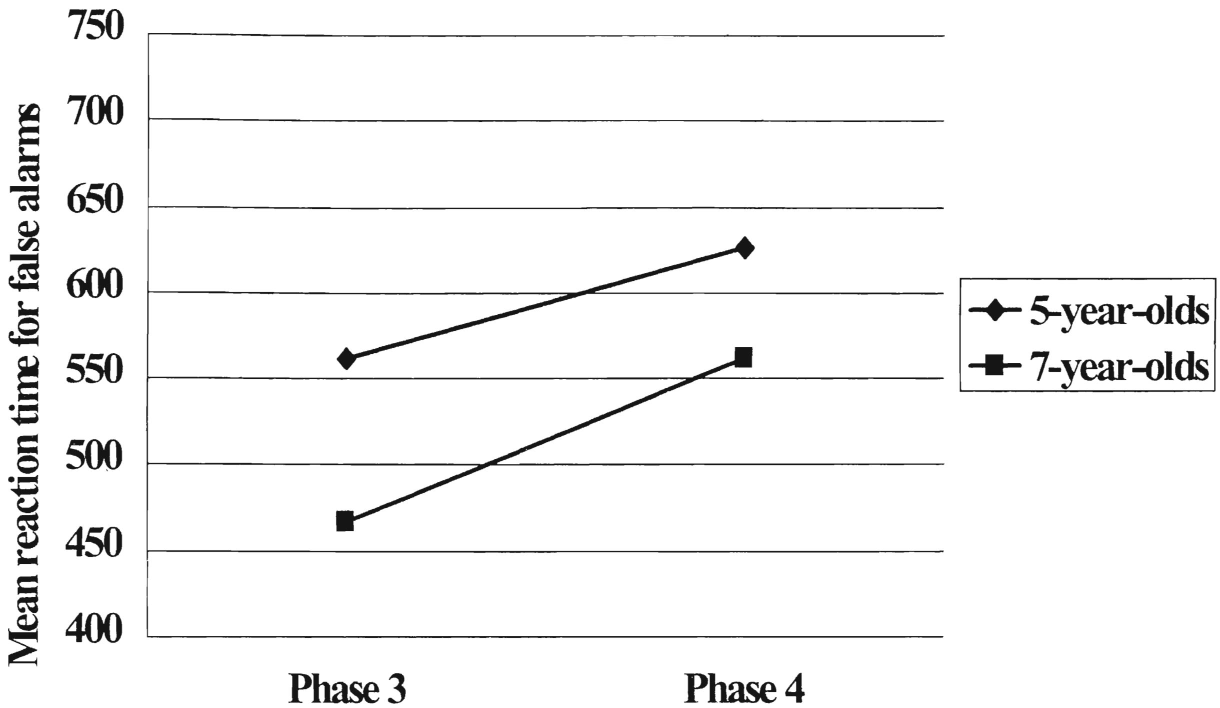

Figure 10. Mean Reaction Time for False Alarms For Each Age Group and in Each Phase

APPENDIX D

IRB APPROVAL FORM

Oklahoma State University
Institutional Review Board

Protocol Expires: 6/12/02

Date: Wednesday, June 13, 2001 IRB Application No AS0171

Proposal Title: DIFFERENTIATING BEHAVIORAL INHIBITION FROM ATTENTION IN 5 AND 7 YEAR OLDS

Principal Investigator(s):

Jami Bartgis
215 N. Murray
Stillwater, OK 74078

Dr. David Thomas
215 N. Murray
Stillwater, OK 74078

Reviewed and Processed as: Expedited (Spec Pop)

Approval Status Recommended by Reviewer(s): Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 203 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

Carol Olson by David S Thomas

Carol Olson, Chair
Institutional Review Board

VITA 2

Jami D. Bartgis

Candidate for the Degree of

Master of Science

Thesis: THE DEVELOPMENT OF ATTENTION AND RESPONSE INHIBITION FOR 5- AND 7-YEAR-OLDS

Major Field: Psychology

Biographical:

Personal Data: Born in Siloam Springs, Arkansas, the daughter of Carolyn Livingston and Larry Jones.

Education: Graduated from Vinita High School, Vinita, Oklahoma in May 1994; received a Bachelor of Arts degree in Psychology from University of Central Oklahoma, Edmond, Oklahoma in December 1998. Completed the requirements for the Master of Science degree with a major in Clinical Psychology at Oklahoma State University in August, 2002.

Experience: Employed by Oklahoma State University, Department of Psychology as a graduate assistant working for the Five-Star Interlocal Cooperative, 2001-2002; worked as an undergraduate and graduate research assistance in the Developmental and Psychophysiology Laboratory at Oklahoma State University, Department of Psychology, 1998 to present.

Professional Memberships: American Psychological Association Graduate Affiliate, Southwestern Psychological Association Student Affiliate, American Indian Psychologists Graduate Affiliate.